REPORT RESUMES

ED 010 765 SE 000 018

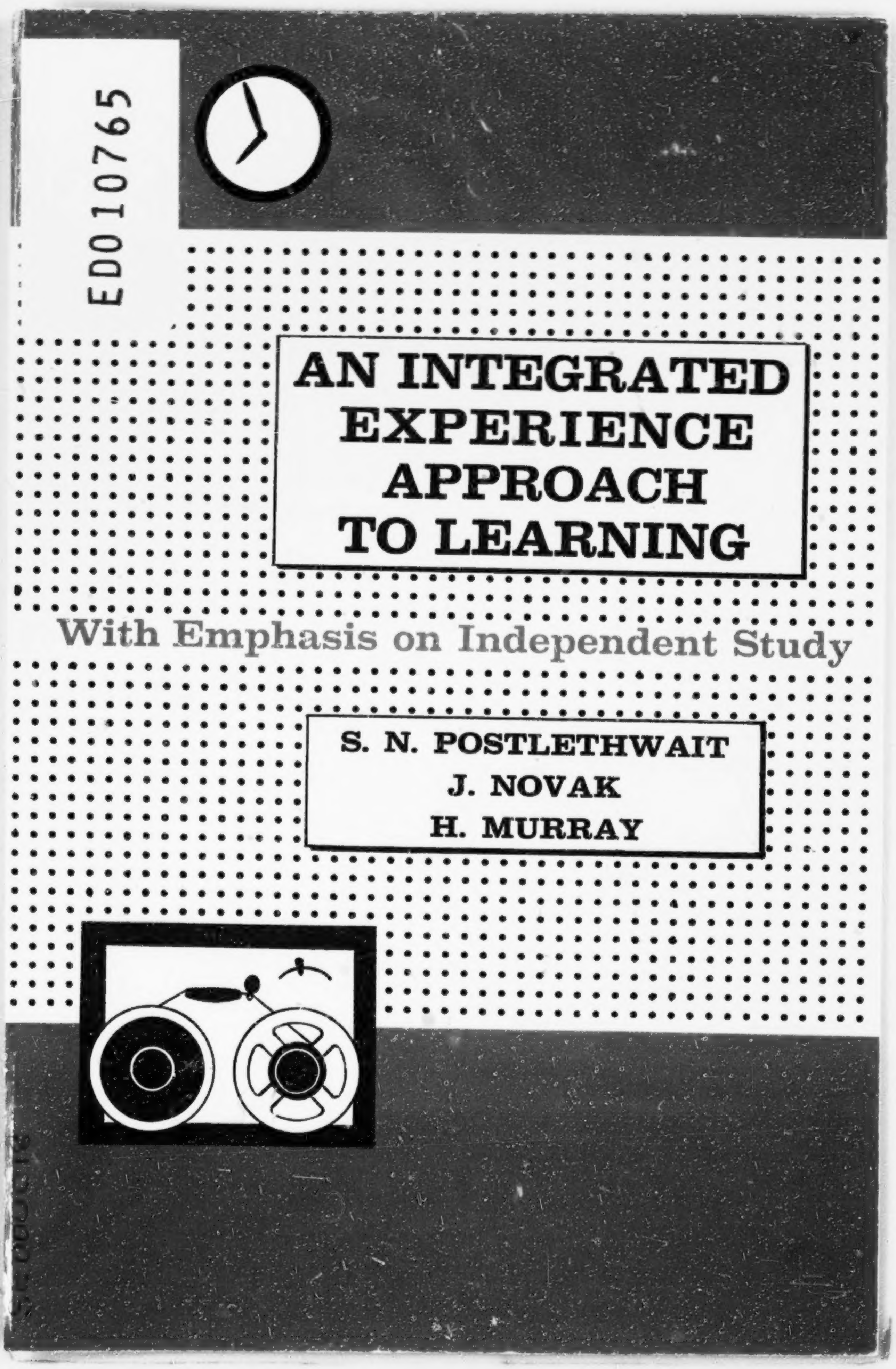
INTEGRATED EXPERIENCE APPROACH TO LEARNING.
BY- POSTLETHWAIT, S.N. AND OTHERS
PURDUE UNIV., LAFAYETTE, IND.

PUB DATE 64

EDRS PRICE MF-$0.18 HC-$4.96 124P.

DESCRIPTORS- *AUTOINSTRUCTIONAL AIDS, *BOTANY, *COLLEGE SCIENCE, *INSTRUCTION, *LEARNING, AUDIOVISUAL AIDS, BIOLOGY, INSTRUCTIONAL MATERIALS, PROGRAMED INSTRUCTION, LAFAYETTE

THE USE OF AUDIOTUTORIAL TECHNIQUES FOR TEACHING INTRODUCTORY COLLEGE BOTANY IS DESCRIBED. SPECIFIC PRACTICES USED AT PURDUE UNIVERSITY TO ILLUSTRATE DIFFERENT FACETS OF THE APPROACH ARE ANALYZED. INCLUDED ARE INDEPENDENT STUDY SESSIONS, SMALL ASSEMBLY SESSIONS, GENERAL ASSEMBLY SESSIONS, AND HOME STUDY SESSIONS. ILLUSTRATIONS AND SPECIFICATIONS OF PHYSICAL FACILITIES AND EQUIPMENT USED AT PURDUE ARE ALSO DESCRIBED. PRACTICAL SUGGESTIONS RELATED TO THE EFFICIENT USE OF STAFF, STUDENT READING ASSIGNMENTS, GRADING, AND THE PREPARATION OF AUDIOTUTORIAL LESSONS ARE INCLUDED. AUDIOTUTORIAL INSTRUCTION IS COMPARED TO CONVENTIONAL INSTRUCTION IN TERMS OF RELATIVE COSTS AND EFFECTIVENESS. (AG)



ED010765

AN INTEGRATED EXPERIENCE APPROACH TO LEARNING

With Emphasis on Independent Study

S. N. POSTLETHWAIT
J. NOVAK
H. MURRAY

AUG 24 1966

AN INTEGRATED EXPERIENCE APPROACH TO LEARNING

With Emphasis on Independent Study

by

S. N. POSTLETHWAIT
J. NOVAK
H. MURRAY
Department of Biological Sciences
Purdue University
Lafayette, Indiana

U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY.

Burgess Publishing Company
426 South 6th Street • Minneapolis, Minn. 55415

AUDIO-TUTORIAL BIOLOGY SERIES

Student guides for use w/Audio-Tutorial System of Teaching.

Postlethwait: Plant Science (Unitized for use with the Audio-Tutorial Approach), 1966

Unit Number	Author	Title	Student Study Guide
2	**Giles**	The Microscope	
3	**Giles**	The Cell	
4	**Sinclair**	Diversity Among Organisms: Protists	
5	**Sinclair**	Diversity Among Organisms: Plants	
6	**Johnson**	Taxonomy and Animal Diversity	
7	**Bond**	Diversity Within Organisms: Plants	
9	**Lutz**	Study of a Typical Animal (Fetal Pig)	
10	**Newell**	Transport Mechanisms	
11	**Abdul-Baki**	Energy and Matter	
13	**Belcher**	Irritability and Coordination	
17	**Westerfeld**	Molecular, Cellular and Organismic Reproduction	
18	**Caswell**	Development	
20	**Caswell**	Inheritance	
21	**Brown**	Skeletal Homologies and Adaptations	

Audio Script w/Teacher's Guide Available for Each Unit, Details upon Request.

These units are available from Minneapolis only.

Copyright © 1964 by Burgess Publishing Company
All rights reserved

Printed in the United States of America

Library of Congress Catalog Card Number 64-8598

2nd Printing 1966

"PERMISSION TO REPRODUCE THIS COPYRIGHTED MATERIAL HAS BEEN GRANTED
BY Kay Pushins
Permissions Editor
TO ERIC AND ORGANIZATIONS OPERATING UNDER AGREEMENTS WITH THE U.S. OFFICE OF EDUCATION. FURTHER REPRODUCTION OUTSIDE THE ERIC SYSTEM REQUIRES PERMISSION OF THE COPYRIGHT OWNER."

Preface

Dr. S. N. Postlethwait introduced audio-taped presentations to augment the instruction in his freshman botany course at Purdue University in 1961. His purpose - then as now - was to offer maximum educational opportunity to students of every background and level of aptitude or skill, even within the framework of a large, multi-section class.

From its inception, the audio-tutorial concept proved its worth by allowing slow and average students to absorb the course material through as many learning processes and as many senses as necessary while freeing the rapid learner, the well-grounded and the good reader to proceed as quickly and in as much depth as desired.

Dr. Postlethwait accelerated the development of the audio-tutorial program in 1962, when enrollment in his course jumped from 380 to 480. At this time, he converted the entire course to the multi-faceted methods approach he had devised, centering on a supervised self-instructional laboratory. Emphasis was shifted from the instructor's pedantry to the student's learning. The senior instructor was freed by the tapes to devote his dedicated time to the real business of teaching - inspiration, motivation, orientation, meaningful personal contact.

A manual designed to accompany the tapes was prepared and made available to other schools, and by 1963 a complete course on tapes and in manuscript form was available.

Introduction of these materials occasioned widespread interest among educators and triggered a flood of visits, correspondence, questions and requests for further information.

This book, then, in part a detailed description of audio-tutorial implementation at Purdue, is the natural outgrowth of the germination of the concept, for considered use in all science laboratory courses. It is designed to answer questions and to serve as both invitation and blueprint for your participation in the continuing growth of a program that represents an unusual opportunity for improved teaching.

About the Authors

SAMUEL N. POSTLETHWAIT, B.A., M.S., Ph.D., born in Willeysville, West Virginia, in 1918, began his teaching career in a West Virginia elementary school in 1940. He was awarded a NSF Faculty Fellowship for study at Manchester University, Manchester, England in 1957, became a fellow of the Indiana Academy of Science (1961), and first came to Purdue University - where he is a full professor in the Department of Biological Sciences - in 1950. Dr. Postlethwait has served on various panels and committees for the American Institute of Biological Sciences, Botanical Society of America, National Science Foundation and the Indiana Academy of Science. He is also a member of Sigma Xi, American Association for the Advancement of Science, International Society of Plant Morphologists, American Society for Cell Biology, Torrey Botanical Club and the International Society for Stereology.

JOSEPH D. NOVAK, B.A., M.S., Ph.D., age 34, a native of Minneapolis, Minnesota, taught general botany and other biology courses and worked with biology teachers at Kansas State Teacher's College before coming to Purdue University in 1959. Currently in charge of undergraduate and graduate programs for biology teachers at Purdue, where he is an associate professor of biology and education, Dr. Novak has contributed to publications of the National Academy of Science-National Research Council, Biological Sciences Curriculum Study and a variety of professional journals. Vice president of the National Association of Biology Teachers in 1963, he now is president of the Association of Midwestern College Biology Teachers and executive secretary of the National Association for Research in Science Teaching.

HAL MURRAY, B.A., M.S., 27, is a native of Coco Solo, Panama Canal Zone. He is now in the process of completing his doctorate. After serving as a teaching assistant in a conventional botany laboratory at the University of Arizona, Mr. Murray came to Purdue University in 1962 as an instructor in general botany under Dr. Postlethwait. Early and intimate participation in the audio-tutorial program has enabled him to add his own contribution to implementation of the concept at Purdue. He is a member of Sigma Xi, Phi Beta Kappa, and the American Association for the Advancement of Science.

Table of Contents

Page

CHAPTER I. THE NEED FOR INNOVATION IN TEACHING 1

CHAPTER II. AN INTEGRATED EXPERIENCE *APPROACH* 5

- Definition 5
- History and Development 7
- Study Sessions 8
- 1. The Independent Study Session 8
  - Supervision 9
  - Preparation of Materials 14
  - Quizzing 16
- 2. The Small Assembly Session 19
- 3. The General Assembly Session 21
- 4. The Home Study Session 22

CHAPTER III. PHYSICAL FACILITIES 24

- Audio-Tutorial Booth 24
- Tape Player 25
- Single Concept Movies 29
- Demonstration Table 30
- Workroom 31
- Other Items 32

CHAPTER IV. AN INTEGRATED EXPERIENCE SAMPLE 34

- The Independent Study Session 34
- The General Assembly Session 67
- The Home Study Session 67
- The Small Assembly Session 74
- Special Research Project 77

Page

CHAPTER V. OPERATIONAL ASPECTS 81

Teaching Personnel 82
Text, Manuals, and Readings 86
Grading System 87
Records 89
How to Prepare an Integrated Experience Lesson 90
*Costs 93
Achievement and Problems of the Integrated Experience Approach 97
1. Student Achievement 98
2. Instructional Advantages 100
3. Continuing Problems 100

CHAPTER VI. POTENTIALS FOR THE INTEGRATED EXPERIENCE APPROACH. 103

Accommodation for Individual Differences 103
Patterns for Utilizing the Integrated Experience Approach. 105
1. The Self-Study Laboratory for a Secondary School Science Department 105
2. The College Self-Study Laboratory 108
3. Cooperative Programs with Other Schools . . 109
4. Other Educational Opportunities Provided by the Integrated Experience Approach. . 110

IN CONCLUSION. 114

---

* see Publisher's note on page 94.

Chapter I.

THE NEED FOR INNOVATION IN TEACHING

Population explosion, knowledge explosion, updating of high school teaching and a general increase in the awareness of the importance of education to a successful life has intensified certain problems in education. Specifically, students enrolled in freshman courses in college now represent a great diversity of interests, backgrounds and capacities. The problem is to provide a learning situation with enough flexibility for each student to make adjustments suited to his individual needs.

Population increase is worldwide and will continue until some method is found to limit the world's birth rate. The world's demographers predict that we will soon run out of living space and that something must be done. Already school systems are becoming painfully aware of the problems that can be created through population explosion. Colleges and universities now enroll nearly five million students - more than double the total in 1951. It is anticipated that this number will double again by 1970. Currently nearly half of the Americans of the appropriate age are pursuing a higher education and this percentage will tend to increase. College and university officials are frantically attempting to expand facilities to accommodate the onrush. Unless substantial new avenues are found, it is a losing battle for which the only answer seems to be limiting the enrollments to the available facilities. Under these conditions many highly talented individuals may fail to achieve their maximum potential.

Knowledge explosion is a natural consequence of better communication and the rapid increase in the number of scientists. In the last few decades, technological improvements have made communication facilities available which exceed the imagination of only a few short years ago. It is said that there are more scientists living today than have lived in all the world's previous history. As their contribution is added to the current body of information - knowledge accumulates in geometric proportion. Incorporation of this new subject matter into the curriculum requires constant revision of course materials and critical attention must be given to course content to assure inclusion of the more pertinent and newer concepts. Teaching methodology must be flexible enough to incorporate easily and effectively new information as it becomes available without disrupting the whole scheme or approach to presentation.

Updating of subject matter taught in high schools and in elementary schools has been an additional factor in the need for developing a flexible program of presentation. Programs sponsored by the National Science Foundation and other agencies are gradually reaching some of the better schools and, as a consequence, many of our college freshmen have been exposed to highly sophisticated courses. Therefore students having equal capacities may differ greatly in the level of subject matter exposure. Placing these people together in one rigid program of study often results in dulling the desire and curiosity of the well-informed student while creating an overwhelming and impossible situation for the student who is ill-prepared.

The machine age has relieved man of many menial tasks. The percentage of the population who earn their living through physical labor has become less, and more and more people find it necessary to make their living through the use of their intellect. Today, only about 8% of the population is engaged in agricultural production and this is a highly sophisticated kind of agriculture. Thus, a college degree has become a necessity. Moreover, many students would obtain a college education at all costs considering that their failure to do so would result in becoming a social outcast and condemn them to a financially restricted life.

The factors discussed above along with other variables result in a great diversity of interests, background and capacity of students now entering college. In order to accommodate this great range of students, there are three major ingredients necessary in our teaching approach. First, it must include a great variety of teaching techniques, and take advantage of all the modern communication media. Each medium must be selected for use on the basis of its effectiveness and efficiency in evoking the appropriate responses. Secondly, these media must be made available in such a way that the students can pace themselves, omitting those things with which they are already familiar and spending extra time where necessary to bring their education up to the level of their colleagues. And, thirdly, personal contact with teaching personnel must be made available to provide motivation and interest. Each activity required of the student must be analyzed in terms of the objective and all busy work which does not really contribute to the student's progress must be eliminated. The teaching method must take into account the fact that individuals may perceive ideas and concepts through different channels -- some can read perceptually, while others must manipulate and handle materials to obtain an adequate understanding of the concept involved. If the goals can be carefully and critically identified, a student arriving at these goals independently along some avenue other than that provided by the teacher, should be accorded the same respect as one who has attended carefully to the details of a program outlined by the instructor. A teacher can only provide guidance, facilities and motivation. The student must do the learning. All too often, teachers develop pet exercises or programs and every student is required to perform faithfully each item if he is to receive a satisfactory grade. Often these pet approachs make little or no direct contribution to the learning process or the student's needs, and only students who are willing to conform and can properly interpret the teachers' wishes can obtain good grades. Creative students who will not submit to the regimentation may receive low grades regardless of their knowledge of the subject.

A possible solution to some of these problems may involve totally restructuring a course or even the entire curriculum of a school. A number of colleges and high schools have already taken steps in this direction (Munster Senior High School, Munster, Indiana, Nova High School, Fort Lauderdale, Florida, St. Louis Junior College District, and St. Louis Country Day School, St. Louis, Missouri, and Antioch College, Xenia, Ohio to mention only a few). The limitations and restrictions commonly imposed by the conventional approach must be discarded and prime consideration given to the needs of the individual student. That is, one should analyze the course objectives, the kind of subject matter to be presented, the ways or means by which it could be best made available to students, and provide the students an opportunity to select those activities which are important and helpful to him. This is not to suggest that effective conventional teaching techniques are to be eliminated from the approach. It merely means that one develops a multi-faceted, multi-sensory approach which takes advantage of every teaching facility that can be made available. Every conventional teaching circumstance is exploited to its utmost. The responsibility for learning and the mechanics for scheduling is placed on the student. The teacher, in many cases, is freed for the real business of teaching, i.e., the orientation, direction elucidation, guidance, and personal contact with individual students which tends to inspire and motivate them to greater effort.

The inconvenience of getting information is an impediment to learning. It is human nature to follow the path of least resistance. If the "getting-of-knowledge" involves wearisome busy work, or activities not associated with the information itself, the desire for learning may be suppressed. Further, impediments which merely delay the getting of knowledge reduce reinforcement and effective learning. A teaching procedure should require frequent response by the student to give him feed-back as to his progress and then allow him to participate in the decision as to whether he has accomplished the objective. The desire for achievement and the common sense of young people is often underestimated. Well-meaning teachers and parents frequently frustrate the very thing they are trying to cultivate through clinging to procedures blindly accepted because of tradition.

Five of the following chapters describe an experiment in teaching a freshman botany course at Purdue University. An attempt has been made to practice the philosophy set forth above in every aspect of the course. While the procedures are explained in minute detail, the authors do not mean to imply that this is the only method by which satisfactory teaching can be accomplished. However, since the results have been especially gratifying, it seemed desirable to share this information in the hopes that others might be motivated to join in an all-out effort to improve instruction at all levels.

Chapter II

AN INTEGRATED EXPERIENCE APPROACH

Definition

Emphasis on student learning rather than on the mechanisms of teaching is the basis of the integrated experience approach. It involves the teacher identifying as clearly as possible those responses, attitudes, concepts, ideas and manipulatory skills to be achieved by the student and then designing a multi-faceted, multi-sensory approach which will enable the student to direct his own activity to attain these objectives. The program of learning is organized in such a way that students can proceed at their own pace, filling in gaps in their background information and omitting the portions of the program which they have covered at some previous time. It makes use of every educational device available and attempts to align the exposure to these learning experiences in a sequence which will be most effective and efficient. The kind, number and nature of the devices involved will be dependent on the nature of the subject under consideration.

The term, "integrated-experience", is derived from the fact that a wide variety of teaching-learning experiences are integrated, with provision for individual student differences, and each experience planned to present efficiently some important aspect of the subject. In the audio-tutorial booth, the taped presentation of the program is designed to direct the activity of one student at a time; the senior instructor, in a sense, becomes the student's private tutor. It is important to emphasize at this point that the tape represents only a programming device and that the student is involved in many kinds of learning activities. Further, it should be noted that those activities which by their nature cannot be programmed by the audio tape are retained and presented in other ways. For example, guest lecturers and long films are shown in a general assembly session, and small discussion groups are held on a regular basis to provide for those activities which can best be done in a small assembly. Flexibility and independence, accompanied by helpful guidance when necessary, are the key concepts of the approach.

In the audio-tutorial system the instructor's voice is available to the student to direct and supplement his study effort. This does not mean that a tape lecture is given!! It refers to an audio programming of learning experiences logically sequenced to produce the most effective student response. Each study activity has been designed to provide information or skill leading to the proper performance of the next activity or else it builds on the foundation of knowledge previously laid. The overall set of integrated experiences includes lectures, reading of text or other appropriate material, making observations on demonstration set-ups, doing experiments, watching movies and/or any other appropriate activities helpful in understanding the subject matter. This system differs from the written programmed instruction and the conventional lecture laboratory approach in several important ways:

1. Most subjects require that a student receive a variety of learning experiences to become properly informed about them. The conventional teaching system recognizes this requirement and attempts to fulfill it through the scheduling of lectures, laboratories, recitations, etc. In the integrated experience system, these activities can be organized in a stepwise fashion with a reduction in the disassociation in time and space encountered in the conventional approach, while at the same time the logical learning progression characteristic of written programmed instruction is retained. Further, the learning events need not be limited to the vicarious participation of the student through his reading only, as in written programs. Hour-long lectures of necessity cover several units of information. Some of these topics are covered more meaningfully when there is associated with them, student involvement through experimentation, observation, textbook reading and other appropriate activities. The limitations of time and physical facilities make this kind of integration unfeasible under the conventional system but are clearly practical under the integrated experience system utilizing audio tape programming.

2. In the audio-tutorial booth the voice of the instructor provides timely information, definitions and parenthetical expressions with minimal effort for the learner. These helpful asides are often omitted from a student's study because of the inconvenience involved in looking up words, and because such thoughts seldom fit well as a part of a written text. The tone of voice places emphasis on important points and expresses authority not sensed through reading the written word.

History and Development

The inception of the integrated experience system as currently employed at Purdue University was in 1961. The senior author attempted to provide an opportunity for students with poor backgrounds to keep up with the class by making supplementary lectures on audio tape. The student could listen to these lectures from 7:30 AM to 11:30 PM on week days and from 12 PM to 11:30 PM on Sundays through the facilities of the Audio Visual Department. The first tapes were purely supplemental lectures. During the progress of the semester, the nature of the tape lectures progressively changed toward an audio programming of a variety of learning experiences. At first, only diagrams and photographs were made available with the tape and the student's attention was directed to various items in these diagrams and photographs while he listened to a discussion about them. Later the student was asked to open his textbook and follow the text explanation while listening to the instructor's discussion of the information. Thus, the author's point of view and the instructor's point of view were considered at the same time. Soon living plants were added to the other materials, and ultimately the student was asked to do experiments from the laboratory manual in context with the study of the text and tape discussion. By the end of the semester, a weekly learning kit was prepared and students could do the full range of study for the week without attending any of the formal sessions of the course. The student's reaction was so favorable to this supplemental material that it was decided to set up an experimental section of 36 students who would receive all instruction programmed by audio tape. During the second semester of 1961-62 this was done. The experimental section met with an instructor only once each week to take quizzes and for a discussion session. They were required to take the same exams that were given to the conventionally-taught group, and at the end of the semester, although they had not done better than the conventional group, they had done just as well. The 36 students were consulted as to how one could best set up a study program for plant science which would incorporate the flexibility desired yet retain the quality of instruction necessary to prepare them for their advanced courses. As a result of these discussions, the course in freshman botany at Purdue has been completely restructured to provide a maximum of student freedom for independent study and an opportunity for him to make adjustments for his interests, background, and capacity. The items included as a part of this program will be discussed during the next few paragraphs.

Study Sessions

The terms lecture, recitation, and laboratory are not used in connection with the integrated experience program in order to emphasize the role of the student in the learning process. The connotation one receives from the term lecture is activity on the part of the individual who is doing the lecturing while students are passive if involved at all. The formality of a laboratory and recitation as conventionally conducted also implies a degree of regimentation of the students. Therefore, the term study session has been adopted for use hoping that it will place emphasis on learning rather than teaching. Four study sessions are involved:

1. Independent study session (ISS)
2. Small assembly session (SAS)
3. General assembly session (GAS)
4. Home study session (HSS)

1. *THE INDEPENDENT STUDY SESSION (ISS)*. --The purpose of this session is to provide the student with an opportunity to engage in the kinds of study activities which can best be accomplished when proceeding independently. It includes a great variety of activities which, by nature, can be programmed by audio tape. Especially important is the inclusion of subject matter and procedures which are likely to be mastered at an unequal rate by many students. It includes such items as short tape-lectures, introduction to laboratory materials, study of demonstration materials, examination of specimens, performance of experiments, reading from textbooks, keying-out specimens, discussion with fellow students and teaching assistants, viewing brief single concept films, making microscope slides, studying specimens through the microscope, collecting and analyzing data, setting up materials for later evaluation, and numerous other activities commonly used in the presentation of subject matter.

The most effective use of this session is obtained when the session is unscheduled and when the study center is available over a large number of hours during the day. Ideally, the laboratory is open from 7:30 in the morning until 10:30 at night, with the student having an opportunity to come in at his convenience. This kind of arrangement allows the student to take advantage of those hours in the day which normally are not feasibly scheduled through the registrar's office, but which for some reason may be convenient to the student. It also enables the student to spend a long block of time studying one subject. He can study until he has achieved some measure of mastery of the subject before scheduling forces him to terminate it. Students who have a weak background can take advantage of the availability of the facilities over an extended period and those students who have been exposed to the subject matter previously or are capable of rapid assimilation of information are not required to spend time in the laboratory idly waiting for other students to catch up. In other words, they are able to do those activities which are meaningful and helpful in their learning, at their convenience and at their own pace. It is unnecessary for a student to remain in the study center when he doesn't feel well or when other studies are so pressing that he is unable to concentrate.

Where it is not feasible to allow the students to arrange hours because of facilities and other problems, it is possible to have some measure of the advantages of the unscheduled system by having the students sign up for a portion of their time and attend ISS on an unscheduled basis part of the time. Piling-up which may occur under the unscheduled system may be avoided somewhat by publishing an hourly record of the number of students present. Students will quickly adjust their schedules so that they will arrive when facilities are likely to be available. Even in totally scheduled learning facilities, the important advantages of the student proceeding independently at his own pace and having an opportunity to do all of his study in context, that is, not having lectures disassociated in time and space from laboratory activities, are possible under the integrated experience system.

SUPERVISION.--An instructor on duty at all times is desirable. He can provide special assistance or individual "help sessions" to those who need it and explore a subject more deeply with those students who are more advanced. The instructor, acting as a monitor, can also serve to keep the intellectual tone of the activities at a level which approaches the study situation in a library and reduces vandalism, loud talking and other kinds of undesirable activities. Further, the teaching assistant can maintain stocks of materials, give special assistance for special kinds of problems which may be too involved for the tape explanation and can call the attention of the students to variations in the program which cannot be included on the tape directions. The student profits by the presence of the instructor in being able to have pertinent questions answered when they arise, and discussions with the instructor enable both the student and the instructor to become well acquainted. Teaching assistants also profit from this close association. Questions which arise are pertinent ones and the effort to explain the subject matter is rewarded immediately by acknowledgement of understanding by the student or else the instructor becomes aware of the deficiency in his teaching procedure. Oftentimes fellow students also become involved in the discussions and an excellent learning situation is developed (Fig. 2.1).

Ideally, in college, a room should be made available with reference books, a coffee urn and smoking facilities for group discussions which might arise de novo. The help session commonly scheduled under the conventional system for a late

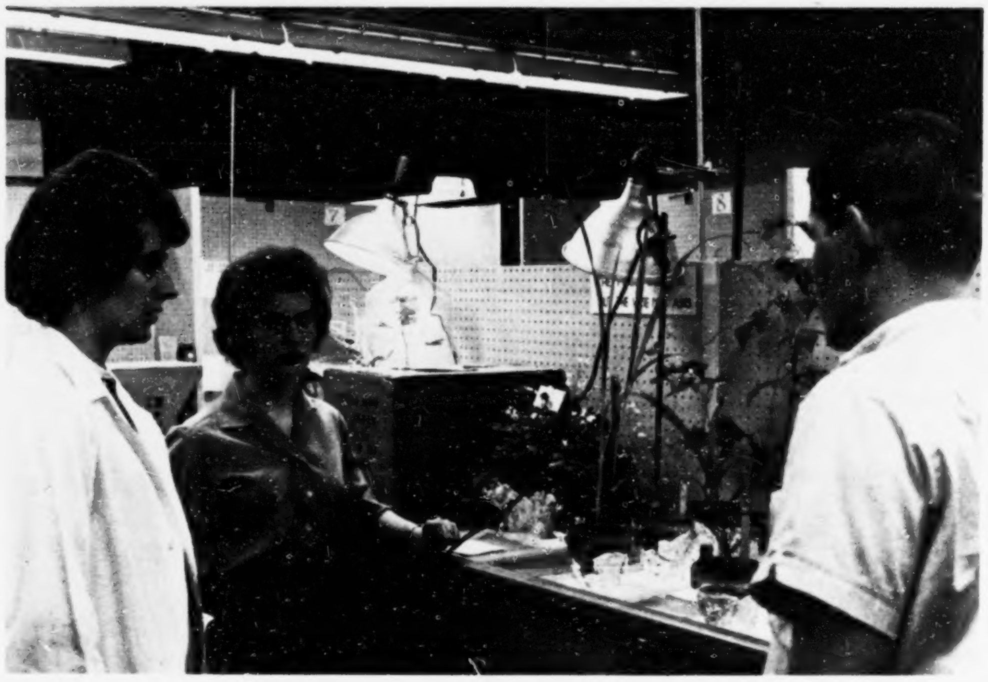


Figure 2.1 - Instructor discussing experiments with students.

evening session, can now be made available to each student and adapted to his individual needs. The initiative lies with the student.

OPPORTUNITIES FOR INCLUSION OF UNUSUAL TYPES OF STUDY.--Certain study activities can be included in the ISS which are impractical under the conventional routine. Single concept films can be used effectively and for the true purpose for which they were designed. Technicolor 8 mm movie projectors or Mark IV 8 mm projectors can be placed on the demonstration table or in the booth and, when a student has progressed to the appropriate point in his study, he can view films especially designed to clarify the subject matter or procedure. Such films include difficult to illustrate phenomena (opening of a flower, time-lapse of mitosis), visual programming of a technique or procedure (how to make a slide, set up an experimental apparatus, use the microscope), and supplemental experiments not feasible with available facilities. The student can view these films as many times as he finds it helpful and, most importantly, they can be viewed in close association with the other study activities related to the subject. For example, the student can listen to the instructor's explanation of mitosis while following diagrams and pictures in manual and text, read about it in Scientific American articles and text, study prepared microscope slides under the microscope, make slides of fresh material, view time-lapse movies of mitosis, and discuss the process with fellow students and instructors all in a short span of time without these study events being interrupted or disassociated by a study of German, History, Physics or some other unrelated topic.

The conventional laboratory involving schedules of 2-4 hours per week limit the nature of experiments to be performed to those which can be done within and at the scheduled times. Under ISS it is practical to assign experiments which require collection of data at irregular intervals and involving variable spans of time. For example, a student might be asked to set up an experiment during one week requiring collection of data at daily intervals for 4 or 5 days and in another week an experiment might involve collection of data at 3-hour intervals over a span of 12 hours.

Special booths containing materials for supplementary study can easily be made available. The Mark IV 8 mm movie projector is equipped for the use of head phones and will accommodate movies up to 25 minutes in length. Movies and audio tapes by distinguished professors on special topics can be made available for those students who wish to pursue a subject more deeply.

MATERIALS. --Perhaps the most effective arrangement for tape use is to have individual carrels or study booths made of pegboard. The details will be discussed later in the chapter on physical facilities. In a study center which is open from 7:30 AM until 10:30 PM, one tape player per 20 students seems to provide adequately for the four-hour conventional equivalent of scheduled classroom time. Each booth or carrel is equipped with material appropriate for the week's study (Fig. 2.2). The carrel always includes a tape player and the tape which programs the study for a given week. Additional materials, as the subject matter may demand, include the textbook, a laboratory manual, live materials, experimental equipment, an 8 mm movie film projector, microscope, demonstration set-ups, charts, posters, diagrams, models, outlines, film strips,

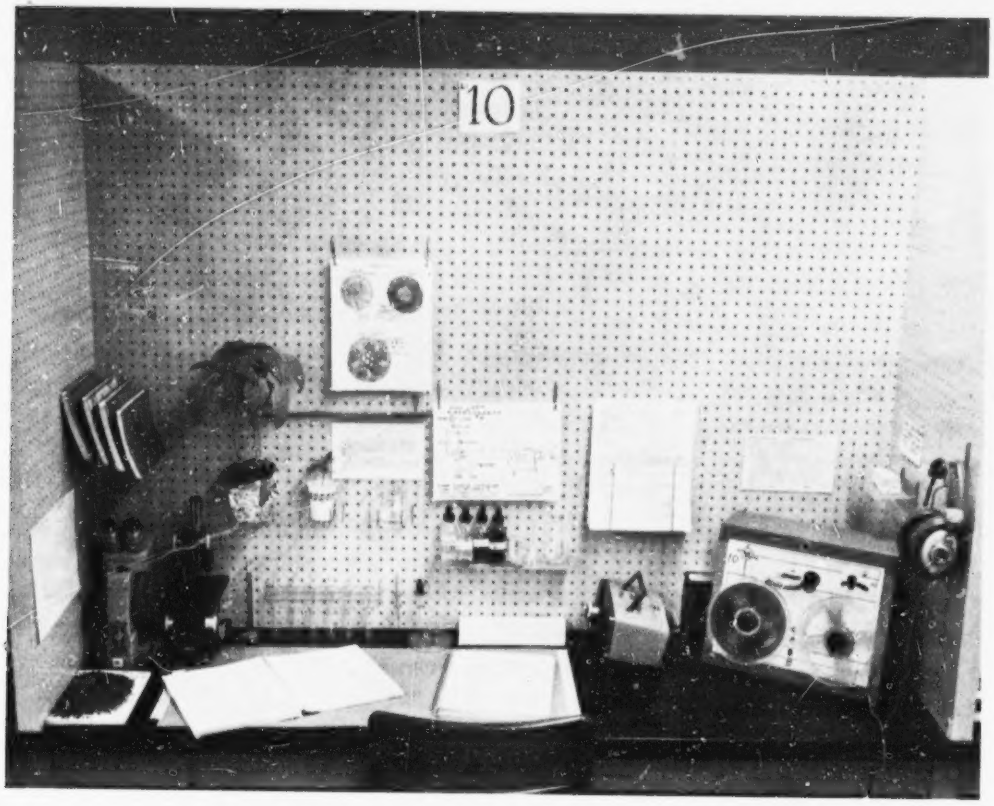


Figure 2.2 - Kinds of equipment frequently included in the booth.

pictures, microscope slides, 2 x 2 slides, and or any other kind of device which might be useful in explaining or demonstrating the subject matter under consideration. Each booth is set-up as attractively as possible and includes as much of the material to be used in the study as is feasible.

Material and equipment too bulky or elaborate to be included in the booths and expensive items which can just as well be studied independently at some central location are placed on a demonstration table (Fig. 2. 3).

The demonstration table should be situated so as to be easily accessible to students from every booth (Fig. 2. 4). The demonstration table includes experimental materials (some of which might be taken back to the booth for use in the booth), demonstration set-ups, partially completed experiments from which data is to be collected, apparatus for doing experiments, and any other appropriate item for study (See Chapter V). If it is desirable to keep a record of the amount of time each student spends in the study center, this is possible through the use of "check-in" and "check-out" cards (8 x 5") (Fig. 2. 5).

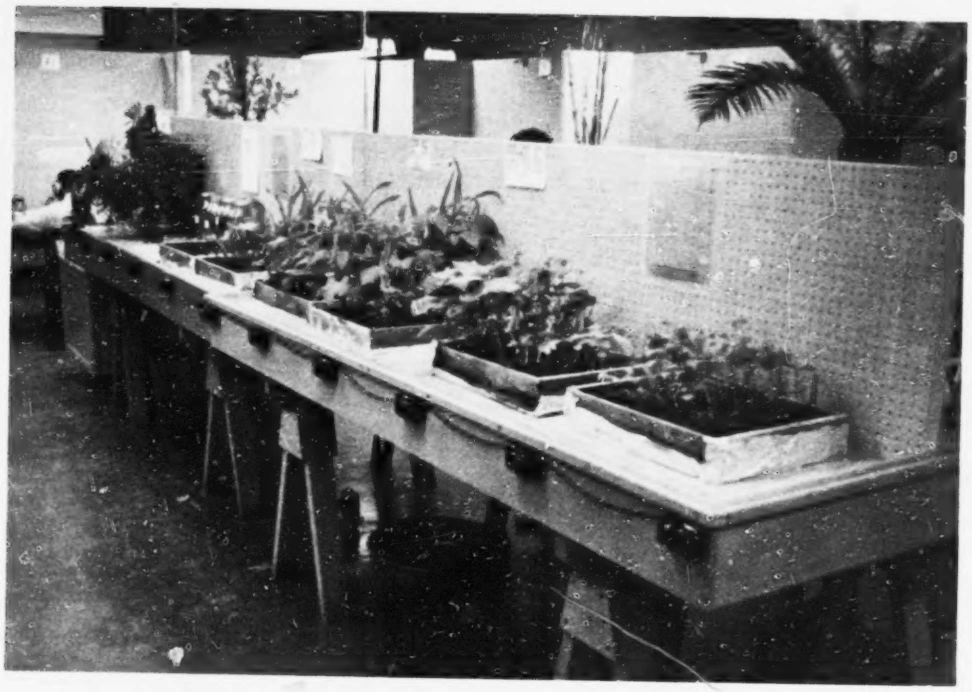


Figure 2. 3 - Demonstration table with material too bulky for inclusion in each booth.

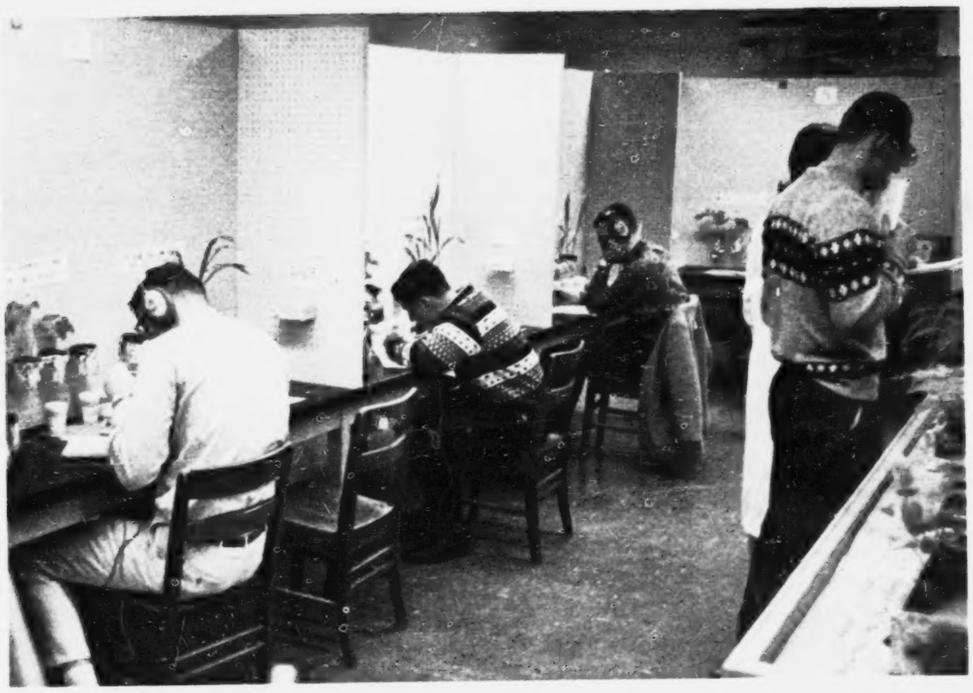


Figure 2.4 - Photograph of booths and demonstration table arrangement. Demonstration table is at the right side of the photograph.

A block of wood with slots numbered to correspond with booth numbers can be used effectively in this regard (Fig. 2.6). The student, on entry into the laboratory, will select his record card from an alphabetized group of cards and record the time of arrival at the study center. He will place the card in the appropriate numbered slot which assigns him to a specific booth. On his departure, the student will reverse the procedure, i. e., he will sign out indicating the time at which he is departing and return the card to the alphabetized group of cards.

PREPARATION OF MATERIALS. --A good plan is to present subject matter on a weekly unit basis with a single tape coinciding with a single week of study. A teaching assistant after listening to the tape can plan and prepare materials to implement it. The preparation and distribution of study materials is of great importance and must be done with extreme care. Much of this work can be done by extra labor personnel once the material has been arranged in a booth as a model. The model booth arrangement along with the

NAME ______________________________
Last First Middle

Wk.	Day	Booth No.	Time In	Time Out
1				
2				
3				
4				

Wk.	Day	Booth No.	Time In	Time Out
5				
6				
7				

Figure 2.5 - Check-out card.

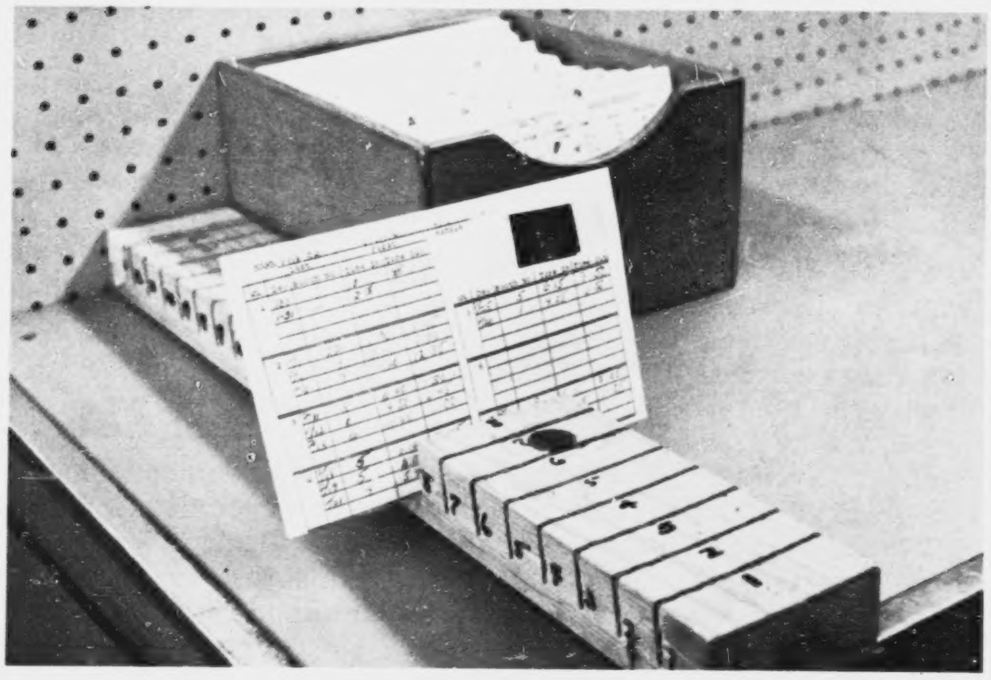


Figure 2.6 - Block of wood used for booth assignment.

development of the materials on the demonstration table can be designed by a teaching assistant.

A considerable opportunity is available to the teaching assistants for creativity through the manner in which they implement the tape study. A limited number of innovations or variations from the original design of the tape can be included through written instructions placed in each booth or on the demonstration table. By assigning one or two teaching assistants to each weekly unit of study, the teaching assistants can take pride in making the laboratory materials effective and excellent in appearance. Also, each teaching assistant feels some major responsibility to the success of the presentation of the course. By noting on the bulletin board that the laboratory for the week is through the courtesy of a specific teaching assistant, the teaching assistant gets credit for the extra effort he may put forth in making the lab an excellent one - contrarywise, teaching assistants who tend to slight their job are "encouraged" to do a somewhat more intensive effort.

Total supervision of all laboratory materials is under one full-time instructor. A weekly meeting of teaching assistants enables them to receive instructions on special details or unusual kinds of laboratory materials and provides continuity to the effort during the following week. This plan has been successful in creating a very good relationship among the teaching assistants and has resulted in high quality study materials. The teaching assistants have developed many new ideas and have made substantial contributions to the success of the entire program.

QUIZZING. --While the nature of quizzing is not unique to the audio-tutorial approach, still a few points concerning quizzes under this system may be helpful. Some sort of weekly quizzing is strongly recommended. A regular quiz in the learning center is highly desirable. It is useful to let the student know if he has made proper progress during the past week, and it prevents the student from procrastination. The authors have operated during the past four semesters with a program of oral quizzing. Each student, upon completion of his study to the point where he feels he has adequately mastered the subject matter, may present himself to the instructor on duty for an oral quiz. He may determine his readiness through self-quizzing (Fig. 2.7), quizzes from colleagues, or prequizzes or discussion given by the instructor. The oral quiz is graded on the basis of 0 to 10 points. The student is

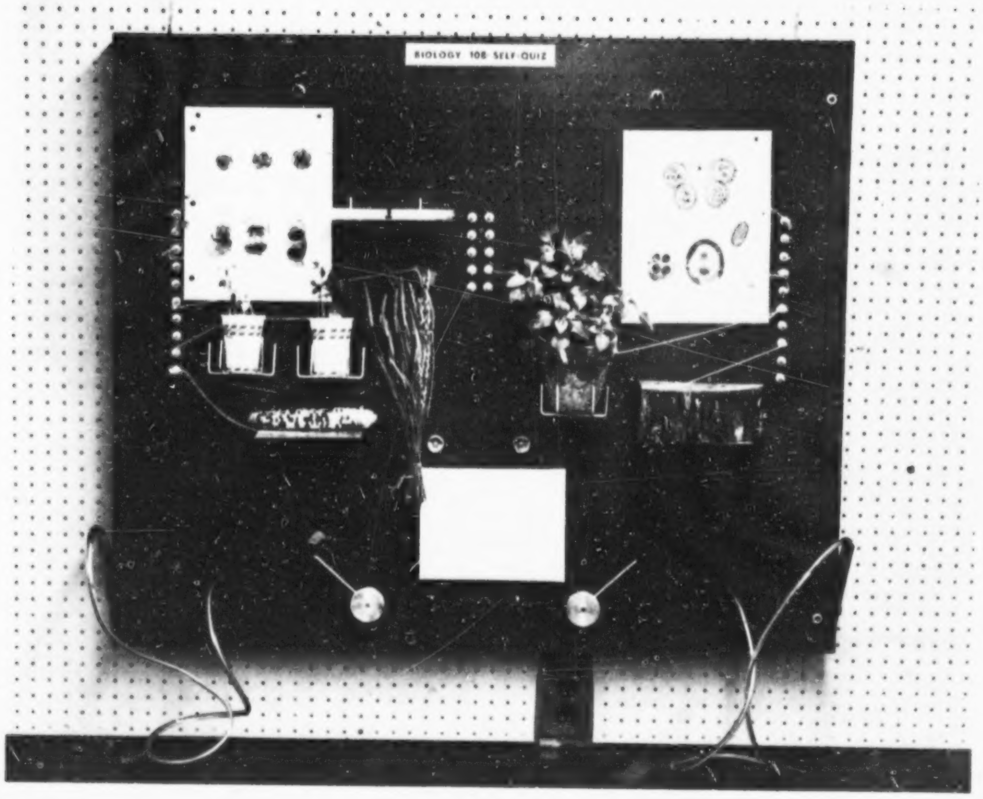


Figure 2.7 - An electronic self-quiz board.
(Courtesy of Peter Loveland)

asked to demonstrate some skill, to expound on some principle which he should have learned from experimental materials available, to discuss a specimen, or, in general, show how much he knows about any particular item which may have been covered in the week's work. As the instructor listens and watches, he attempts to evaluate the student's progress. If the instructor is impressed with the high level of information which the student has attained, he is assigned 10 points. If the student knows absolutely nothing, of course, he is assigned 0 points. More likely, a student will fall somewhere in a range of 5 to 10 points, 6 points being considered as a passing score, 7 as a C grade, 8 as a B grade and 9 as an A grade. The test will proceed until the teaching assistant feels that he can properly evaluate the student's knowledge. Students with whom he has already had contact and feels competent to evaluate he may ask to perform an exercise or to expound on some aspect of the subject briefly and then assign the student a grade. On the other hand, a student who is slower in expression may take up to 10 minutes to display his command of the subject. The net effect of oral quizzing essentially has been to provide the student an opportunity to prepare short talks concerning the various topics included in the subject matter for the week. The emphasis of study is to prepare himself by discussions with colleagues and by delving into the subject as deeply as possible within the time available rather than trying to outguess the instructor as to the number and nature of questions which may be asked. The injustices which may result from misevaluation are minimal and are less severe often times than those imposed by the conventional written questions which may be misinterpreted by the student or may require a qualified answer. It gives the student experience in oral expression and there is a better communication between the teacher and student as to the exact level at which the student may have achieved.

Since the student may take his oral exams at any time when he feels he has mastered the subject matter, the aggressive student can now complete his study in the early part of the week or at his convenience. One big disadvantage of this type of testing is the tendency on the part of many students to procrastinate to the end of the week, such that there is a pile-up of students for quizzing on the last days. Another factor contributing to the pile-up is that many students wish to repeat the study a number of times during the week. This problem has been overcome fairly satisfactorily by determining the number of students which may be quizzed over a given length of time and having students sign up for a specific time for their quiz during the last two days of the week. Students who wish to be quizzed earlier in the week may do so at their convenience.

By the same procedure, it is possible to have students sign up for longer summary practical exams at mid-semester and at the end of the semester. The longer tests can be given in the study center or in any available laboratory where the materials can be set up on display at stations around the room. Students can sign up for the test in groups of 25 or 50 depending upon the number of stations, or individually to arrive at one-minute intervals throughout the day. Naturally the quizzing stations must be monitored by at least one or two teaching assistants at all times. The students may be advanced from station to station through the practical testing set-up by signals at minute intervals from a tape on a conventional type tape player.

While it seems to the authors that the oral type of quizzing has considerable merit both from the point of view of the student and the opportunity of teaching through the use of the quiz, any other type of quizzing which will evaluate the student's achievement and inform him of his progress would be acceptable. Conventional typewritten quizzes could easily be supervised in this session by the teaching assistant while he goes about his other duties or else quizzing could be delayed until the small assembly meeting.

In summary, the ISS is best conducted in a learning center equipped with individual booths and under the constant supervision of an instructor. The student should be able to come and go at his convenience, pacing his study to suit his ability and his other work schedule. Subject matter is presented on a weekly basis which is terminated for each student when he is satisfied that he has mastered the subject matter and has taken a 10 point oral quiz. The student learning activities are programmed through the use of audio tape and may consist of short lectures, explanation of charts and pictures, exercises from the laboratory manual, making observations of demonstration materials, discussions with other students, discussion with the instructor on duty, viewing single concept films, and any other item which may contribute to the progress of the student.

2. *THE SMALL ASSEMBLY SESSION (SAS)*. --The purpose of the small assembly session is to bring together a small number of students with an experienced discussion leader to do many of the items ordinarily accomplished in a conventional recitation session. It is a scheduled session which meets routinely each week and is in charge of the same instructor throughout the semester. The students thus become identified with this instructor as their teacher in the course and will consult with him about problems of absences, grades and other such items needing clarification (Fig. 2.8). The instructor becomes well acquainted with each student and keeps abreast of his progress. He can anticipate those students who are having difficulty and provide appropriate counseling. In keeping with the basic philosophy of the audio-tutorial approach no single format is retained for the small assembly session. The activities in the small assembly session may be properly integrated with the other study sessions and adjusted to fit the nature of the subject matter being presented that particular week. Therefore, a great variety of activities may be directed by the SAS instructor. Commonly it has been the practice of

Figure 2.8 - Instructor Hal Murray presides over a meeting of 25 in freshman botany during SAS.

the authors to use a portion of this session for testing. Tests given on these occasions have been of the conventional written type. However, it is possible to carry in specimens, diagrams, charts, models, slides and other items which would make the test of a more practical nature. In some cases a major share of the period may be devoted to a help session which will involve a discussion of homework problems or subject matter still needing clarification from the independent study session. Commonly no new subject matter is introduced at this session although this is a possibility if the situation seems to warrant it. The small assembly session is an occasion for clarification of announcements and informing students of various procedures which are not covered elsewhere.

Projects involving team work or individual research assignments can be supervised by this instructor. During the course of the semester students are required to do three miniature research projects. The projects are designed to familarize the student with the scientific method. The procedure to be followed is fully outlined in the first problem and progressively less directions are given for the subsequent problems. In problem one the student is told what to investigate, what methods and materials to use, what data to collect, and he is asked to analyze these data and write up the project as a scientific paper. In problem two the student is told what to investigate and what methods and materials to use, but he decides what data to collect and how to analyze them and writes up the project. In problem three the student is told what to investigate but he decides what materials and methods to use, what data to collect, and makes an analysis of these data and writes up the project.

In addition to the above, this session can be used for group activities such as a short field trip, collection of data from long range experiments on a semi-demonstration basis, problem analysis, the showing of single concept films or any other activity best suited to a small group assembly.

3. *THE GENERAL ASSEMBLY SESSION (GAS).* --All students in the course assemble in a large auditorium one hour per week on a scheduled basis. The instructor in charge of the course directs the study during this session. This session may include the giving of general directions and announcements, long movies, guest lecturers, problem solving and items of this nature; but most importantly, it is an occasion for integrating and elucidating the subject matter so that the student may appreciate its significance. The main objective in this session is to project to the student a personality for the course and to set an intellectual tone. Major effort is directed toward motivation. All students thus become acquainted with the senior instructor in the course and thus are able to connect the voice on the tape with a personality. (This is not to imply that this is the only contact of the senior instructor with the students for he should serve as instructor in as many small assembly sessions as possible and as a monitor in the independent study session as well.) The general assembly session is useful in enabling the senior instructor to become acquainted with the students if he so desires. Each student is photographed with his name card on 35 mm film during the first small assembly session. Contact prints of these negatives are made and these photographs are mounted on a cardboard seating chart in the same arrangement as the students are assigned in the general assembly session and the cardboard is placed in front of the senior instructor's office desk. Through this means, it is possible to refer frequently to the

photographs and reinforce the association of names and faces of the students. The association of name and face is begun by a meeting of the senior instructor with small groups of ten students in the greenhouse at the beginning of the course. Ten students sign up at 15 minute intervals and the senior instructor spends two to three days in the greenhouse just becoming acquainted with the students during the first week. Through this initial contact, the photographs, and contact through serving as instructor in the SAS and as monitor in the ISS, it has been possible for the senior instructor to learn the names of 75% or more of over 400 students well enough to recognize the student and call him by name on the street or on the campus.

4. *THE HOME STUDY SESSION (HSS).*--It is anticipated that the student will do the usual amount of outside study expected in a conventional course. This, of course, would include reading of the text, discussion of subject matter with colleagues, and the study of outlined material and notes taken from the independent study session, small assembly session and general assembly session. In addition, the student obtains a set of homework problems from the small assembly session each week. The homework problems will cover the following week's work and will serve as a basis for several of the questions on the 20-point SAS quiz. The authors have not required that homework problems be written out or turned in, for it has been our experience that the use of these as a source of questions for the quiz is adequate motivation for student study. Commonly, the problems will provide data and require an analysis of these data involving an understanding of the facts learned in the independent study session. The answers to these problems may be made available to the students through publication on a bulletin board or mimeographed on the back of the problem sheet. This idea is patterned after the practice in many mathematic texts which provide problems for drill purposes with the answers in the back of the book. The problems are useful to help the student determine if he has learned the facts correctly and gives him practice in analyzing data and problem solving. It places emphasis on certain points to guide the student to important information and avoids some of the rote memory aspect of biological study. It forces collaboration and discussion sessions in the student housing units which provides excellent learning situations.

Certain Scientific American articles are assigned for outside reading. These articles have been carefully selected to supplement the regular text and to provide an extension of the research experience for the student. These articles expand the student's perspective of science and give him some idea of the current kinds of investigations that are being conducted. Since the information included in these articles is usually supplemental, motivation to read them is provided through the inclusion of bonus questions of 1-3 points on the weekly quiz.

Chapter III

PHYSICAL FACILITIES

Contrary to the first impression of many people, the integrated experience system is not expensive. Instead, there are many savings in time, space, and staff effort, once the program is initiated and in progress. For the most part, the program can be made effective with simple modification of existing laboratory facilities. Basically, there is required a learning center or a laboratory equipped with an appropriate number of booths, a demonstration table, a prep room, a recitation room, a lecture hall, a greenhouse, and or an animal house if desirable.

Audio-Tutorial Booth

Booths can be built inexpensively by the use of pegboard partitions on ordinary laboratory tables (See Fig. 3.1). When the learning center is made available from 7:30 AM until 10:30 PM five days per week, one booth per 20 students is adequate. A booth 48 inches tall, 36 inches long and 20 inches deep has been found satisfactory. Other dimensions might serve as well or better depending upon the type of subject being taught. Pegboard partitions provide flexibility for variations in the displaying of material as the subject matter changes from week to week. Ordinary laboratory height table and chairs are satisfactory and need no further comments here. The Kewaunee Technical Furniture

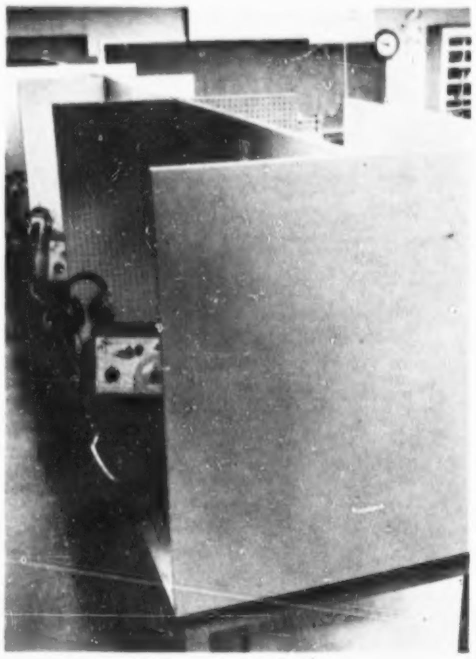


Figure 3.1 - A satisfactory type of booth construction.

Company has designed special booths for use with this system and these are available at a nominal cost.

Each booth is equipped permanently with a tape player. The tape player may be mounted above the working space and operated by remote control, or it may remain on the table top within easy access of the student. The authors have kept the booth free of other equipment by moving in such things as a microscope or 8 mm movie projector only on those occasions when they are required in the study for the week (Fig. 3.2).

Tape Player

The tape player used by the authors was produced by the Audio Visual Department at Purdue University (Fig. 3.3). Following is a verbatim copy of directions for the production of these tape players written by L. D. Miller of the Audio Visual Department of Purdue University. It is reprinted here with his permission.

A TAPE LISTENING DECK FOR STUDENT USE

The Purdue Audio-Visual Center has a large library of taped materials that are used for individual study. Presently over 400 students per day use some of these tapes in the 58 study stations available to them. Average use time is a little under fifty minutes for each item checked out. The tape decks, all of one make, were selected because of their ease of operation, safe handling of the tapes, moderate first cost and small maintenance.

To protect the recordings against erasure a play only machine was selected. A few record-play machines are available for those students who need them but none of the library tapes are to be played on them.

To make a self contained unit, eliminate the heat from tubes, and to enable us to install the amplifier inside the deck enclosure a transistorized amplifier was tried out and accepted for all of our future units. Happily, a saving of about $25 per unit was made by the change to transistors.

The tape deck, consolette, amplifier, battery and other items are all standard parts obtained from local photo or electronics parts distributors. Their assembly is not beyond the ability of an experienced amateur and requires no specialized tools.

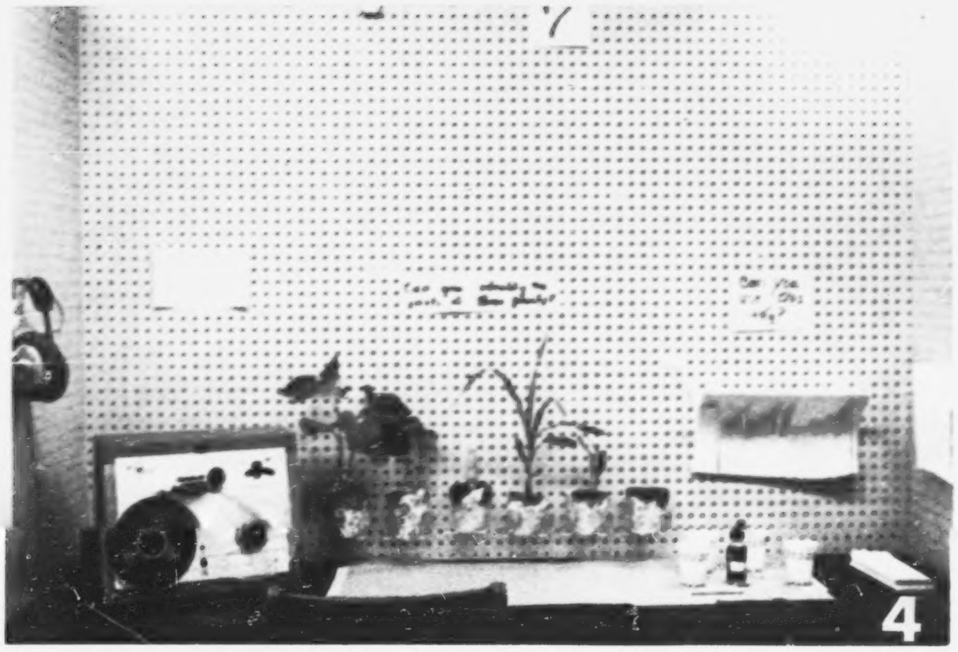


Figure 3.2 - A booth equipped for an ISS.

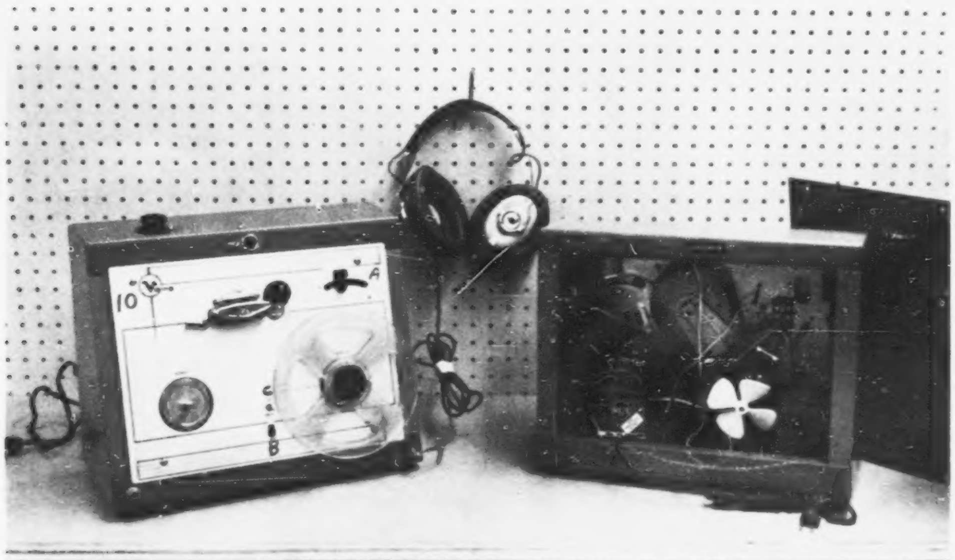


Figure 3.3 - Front and back view of a tape player.

Following is a list of parts we are using:
- 1 ea Tape deck, Viking, half track, monaural, playback only, model #76LP, with DPST switch instead of SPST
- 1 ea Consolette, Viking, for model #76LP deck
- 1 ea Set headphones, low impedance
- 1 ea Amplifier, audio, push-pull, Lafayette PK-544
- 1 ea Dry cell, 9 volt, RCA VS-306 or equivalent
- 1 ea Potentiometer, 10K ohm, C taper
- 1 ea Terminal strip
- 1 ea Phone jack
- 1 ea Volume control knob
- Miscellaneous bolts and covered hook-up wire

By purchasing the above in sets of eight or ten at a time, the complete cost has been less than $115 per complete unit. Assembly time, after the first one, should take about two and one half hours A hook-up diagram will be supplied if requested from our Center.

A few words of caution need to be offered. Be sure to attach the right wires to the switch since a connection to the wrong side will feed 115 volts to the amplifier with resulting damage to it. If hooked to the correct side of the DPST switch, the drain on the battery stops at the same time the motor power is cut off. Incidentally, battery life under heavy use has been about 10-12 months.

A thin sheet of fiber or heavy cardboard should be cut and fitted between the circuit board of the amplifier and the metal consolette as the amplifier is bolted into place. It is easier to attach the wires to the switch before the deck is fastened to the consolette. Further, a small piece of plastic tape should be wrapped around the switch to keep it from contacting the frame.

The transistor amplifier output has an impedance of 8 ohms so that headsets of this value (or slightly higher) should be used. A considerable mismatch will cut down on the frequency response and/or volume. Headsets of 50 ohms can be used by placing a 10 ohm resistor across the output terminals. A frequency response of 100 to 8,000 cps is about average for the ones we have. Tests show it to be surprisingly flat across this range with a good signal to noise ratio. The output is adequate to drive two headsets or a 12 inch speaker.

We have these decks installed in booths and on counters. The former method is preferred but no great objections have been raised when the booth is not furnished. However its omissions with its usual soundproofing will definitely raise the room noise level.

Handles may be attached to the top of the consolette so that the whole unit may be easily transported. This should be done where the player is to be checked out by students for use in a typical library situation. This is being done on some of the Purdue Extension Campuses.

Other tape players can do the same job as the one mentioned here but we suggest it to you as one way to provide an inexpensive, uncomplicated, tape player for self-study purposes.

The authors have found these tape players to be satisfactory but by no means the only possibility for effective audio-tutorial approach. It is possible that several other commercially produced tape recorders could be converted to tape players only and might equal these tape players in performance. These tape players have been in use for four semesters and have been used by over 1, 200 students and still are capable of giving indefinite service. Covers on the earphones become worn and occasionally need to be replaced. Routine maintenance has been required throughout the four semesters of use.

It is anticipated that eventually the tape players will be mounted on a shelf at the top of the booth and all tape players will be operated by remote control by the student. While there

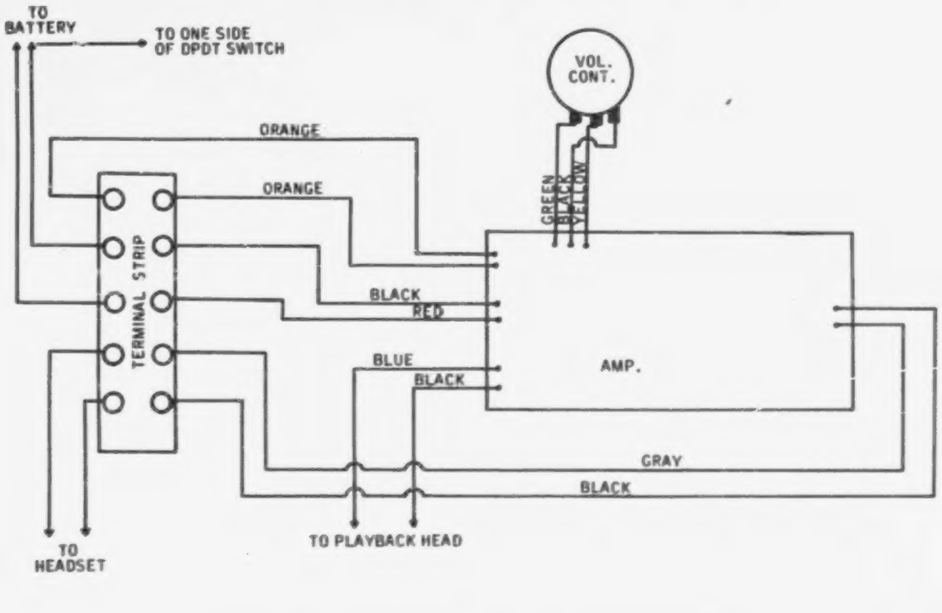

TO BATTERY
TO ONE SIDE OF DPDT SWITCH
VOL. CONT.
ORANGE
ORANGE
GREEN
BLACK
YELLOW
TERMINAL STRIP
BLACK
RED
BLUE
BLACK
AMP.
GRAY
BLACK
TO PLAYBACK HEAD
TO HEADSET

Figure 3.4 - A schematic drawing of a tape player.

is little vandalism with the materials in the learning center, occasionally even good students idly "doodle" and do some damage to tape players. A footage indicator would be very useful but has not been included on the tape players used by the authors. This device would enable the student who wishes to interrupt his study to record the point on the tape at which he is stopping and on his return at some future time he could quickly locate this point and continue his study. Further investigation is necessary before a strong recommendation can be made concerning a most effective tape player.

Single Concept Movies

The integrated experience system provides an ideal opportunity for the use of single concept movies. The author's learning center is equipped with a Technicolor 8 mm projector for each booth (Fig. 3. 5). This movie projector uses plastic cartridges loaded with a single loop of film. No rewinding is

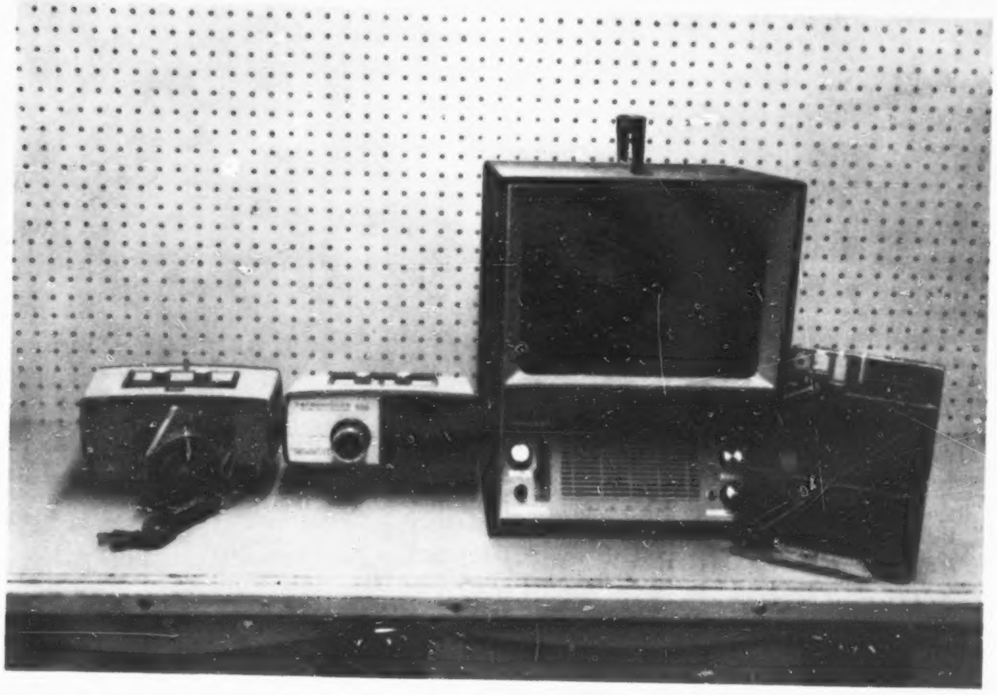


Figure 3. 5 - Technicolor 8 mm projector and Fairchild Mark IV 8 mm projector. Both projectors use cartridge-loaded single loop films.

necessary and the loading process merely involves the insertion of the cartridge into the projector and turning the "ON" switch to start the showing. When the cartridge is removed, it serves as the storage container for the movie film and protects the film from fingerprints and dust from the surrounding atmosphere. A number of such cartridges can be placed in the booth and numbered for use at the appropriate time and in context with the subject matter being presented. The student is at liberty to play the film over as many times as is desirable for him to understand the subject matter being presented. The movie projector being used by the authors is without chrome trim, and does not have a retractable extension chord or the zoom lens. It does however have the mechanism for stopping the film at any point so that a single frame can be viewed as long as desirable.

In addition, two Mark IV 8 mm movie projectors with built-in screen produced by the Fairchild Company are placed in special booths (Fig. 3.5). Films used in these projectors are supplementary type films which enrich the students' study and enable them to go more deeply into a specific subject within the limits of the library of materials available. The Mark IV projector is equipped for sound through the use of a magnetic strip and can be listened to through headphones or through a speaker system built into the projector. Both kinds of projectors play an important role in the presentation of subject matter and are useful items of equipment.

Demonstration Table

Materials which are too bulky or for some reason are not feasibly included in the booths are placed on a demonstration table. The demonstration table used by the authors is a very simple one converted from old sand boxes and supported by ordinary wooden horses. These tables are outfitted with a series of electrical outlets spaced two feet apart all around the margin of the table. The tables are four feet wide by eight feet long and two of these tables are used. The tables are placed end to end (Fig. 3.6) and partitioned longitudinally by a pegboard divider which serves as a backdrop for the mounting of charts, diagrams, and other explanatory material as well as distribution of plant material or other study items. A more elaborate table including such facilities as vacuum, gas, distilled water and tap water might be more useful. Perhaps it

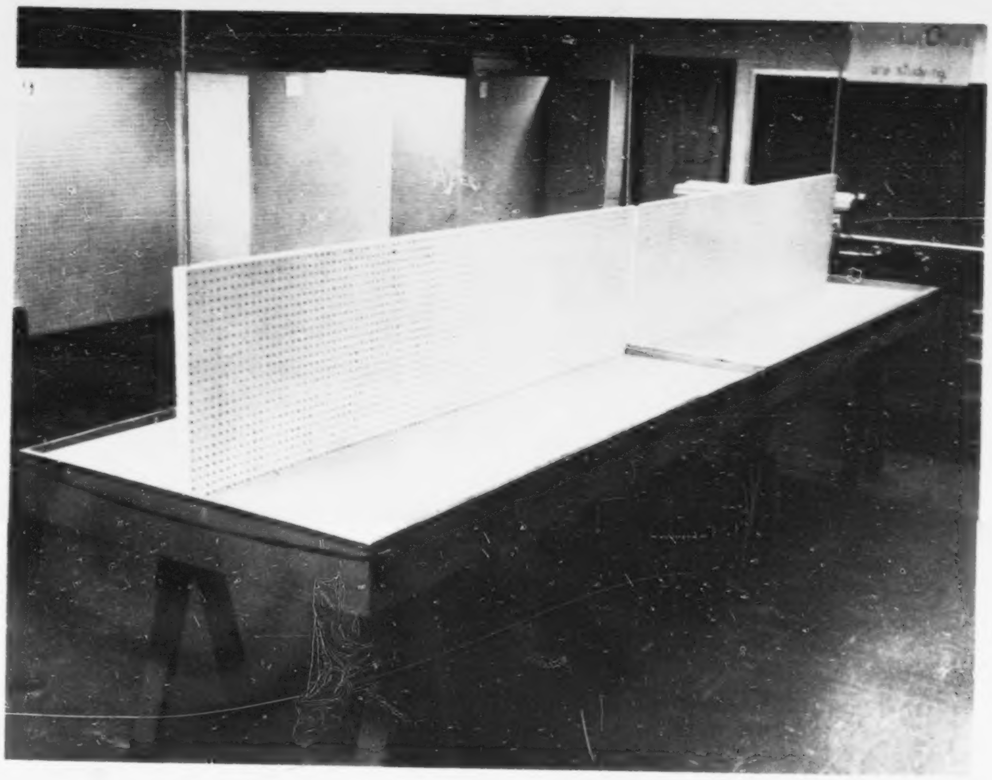


Figure 3.6 - A demonstration table.

would be possible also to include growth chambers, a refrigerator, incubator and oven. While these latter items may be desirable, they are not required in a presentation of a botany course. The demonstration table needs to be placed in a central location readily accessible to all the students from the booths. Perhaps the best arrangement of booths within a study center is to have the booths aligned around the walls in such a way that all students can walk directly to the demonstration table and so that the instructor monitoring the lab can have quick access to all booths and give assistance without interferring with other students.

Workroom

It is highly desirable to have a workroom adjacent to the learning center for students who are doing long-range projects.

The nature of some of the miniature research problems involves the student for four to five hours of continuous experimentation. Often these experiments must be done with the student sitting at a table with a spread of equipment which cannot be accommodated in a single booth arrangement (Fig. 3.7). This workroom should be equipped with appropriate shelves, various kinds of experimental materials, a sink and attendant facilities, and a table and chairs. It is possible that this room can also double as a prep room and maybe, on occasions of less intensive use, it could serve as a "break" room for smoking, coffee or cokes. This would enable the students to get involved in discussions on an informal basis and become better acquainted with each other as well as with instructors who might be on hand.

Other Items

Items associated with the equipping of the booths, such as pegboard fixtures (Fig. 3.8), dropper bottles, hand-out sheets, etc. can be stored in appropriate cabinet space. It is also helpful to have a microscope cabinet to accomodate microscopes

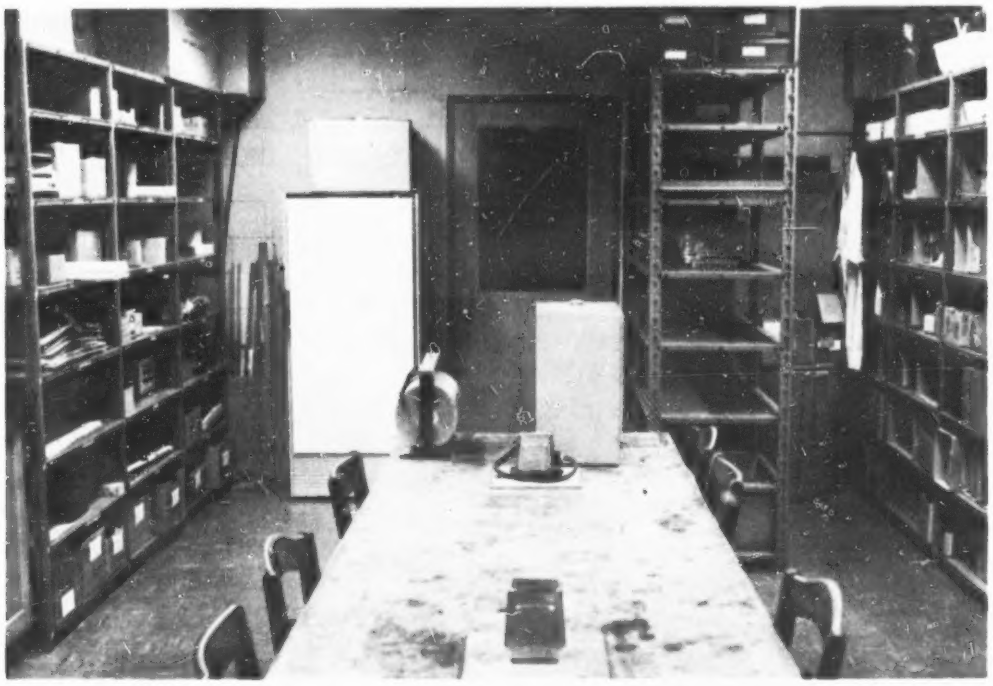


Figure 3.7 - Student workroom.

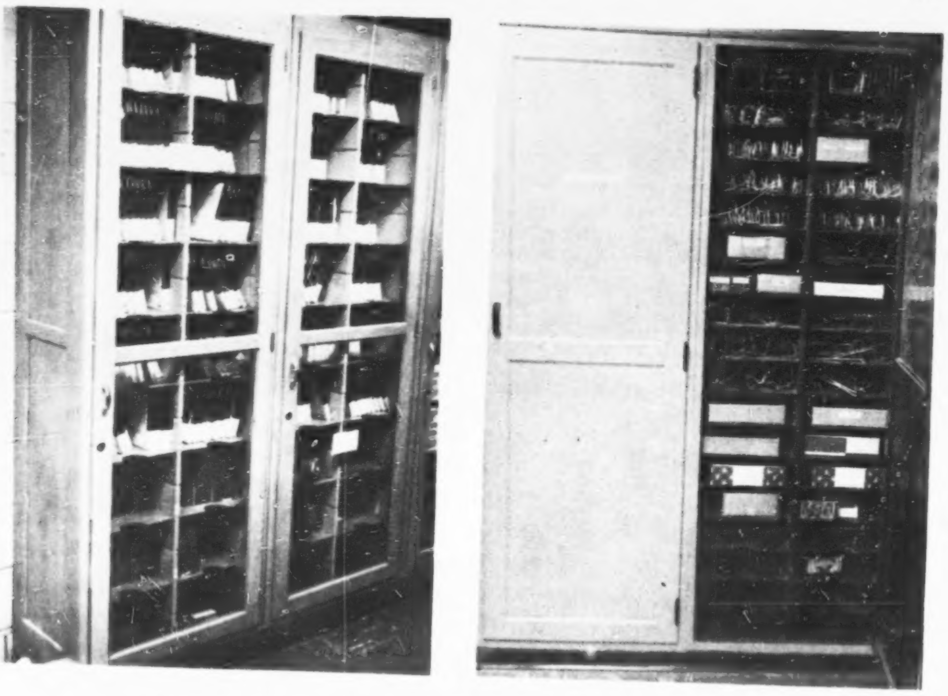


Figure 3.8 - Tape storage cabinet and pegboard fixtures.

not in use. A cabinet for storage of tapes, extra headsets, and spare batteries is desirable (Fig. 3.8). A blackboard on one end of the room is imperative for use by the instructor on occasions when one to several students need specific and private instruction.

It is helpful to have an instructor's desk in the study center. This desk can serve as the home of check-in--check-out cards, the wood block for booth assignments, a suggestion box, and various other items of this nature.

Chapter IV

AN INTEGRATED EXPERIENCE SAMPLE

This chapter includes an example of an integrated lesson as it might be programmed for the students. The tape has been transcribed, manual pages have been reproduced, and the plant materials have been photographed so the reader may partially experience the kind of programming that is possible under the audio-tutorial setup. The unit of information to be treated is entitled "Growth and Development" and involves two week's work. Only the first week's study is included. The general assembly session, the small assembly session and the independent study session will be discussed in appropriate sequential relationship to the other students' activities and the nature of the activities will be described as completely as possible.

The Independent Study Session

The first exposure to growth and development during the two week's study is in the independent study session. The reader should visualize himself as having arrived at the learning center and as he reads the transcription of the tape, he should recognize that the student would be hearing this information presented through the earphones of a tape player and in the voice of the senior instructor. The transcribed words of the audio taped information are in small print to separate it from the text of this book.

The audio taped lesson follows:

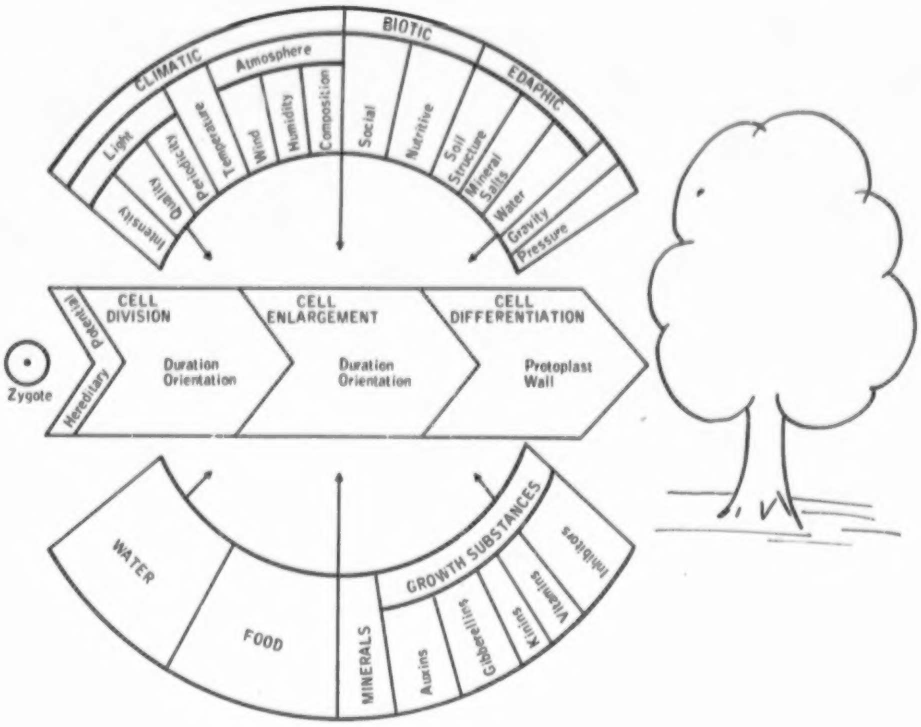
PLANT SCIENCE - TAPE 10 - ENTITLED PLANT GROWTH AND DEVELOPMENT

On this tape and the succeeding one our objective is to examine the most baffling yet the most intriguing problems of biology - that is - what factors and mechanisms control growth and development.

A plant body is derived from a single cell, zygote or spore, through a series of highly coordinated events. On a cellular basis, form results from three major events.--

Cell division - its amount and the plane of division.
Cell enlargement - its amount and the direction of cellular expansion.
Cell differentiation - which may involve changes in composition of the cell wall and protoplast.

Since form is inherited, these cellular events must be controlled in some way by the action of genes. Genetic instructions however can be greatly modified and their expression altered by innumerable factors both internally and externally. Perhaps it would be helpful to visualize these thoughts by use of a diagram. Study the diagram which has been placed before you in the booth.


CLIMATIC
Light
Intensity
Quality
Periodicity
Temperature
Atmosphere
Wind
Humidity
Composition
BIOTIC
Social
Nutritive
EDAPHIC
Soil Structure
Mineral Salts
Water
Gravity
Pressure
Zygote
Hereditary Potential
CELL DIVISION
Duration Orientation
CELL ENLARGEMENT
Duration Orientation
CELL DIFFERENTIATION
Protoplast Wall
WATER
FOOD
MINERALS
GROWTH SUBSTANCES
Auxins
Gibberellins
Kinins
Vitamins
Inhibitors

The cell must contain all the genetic information necessary to control heritable traits of the mature plant. This is indicated on the chart by labeling the beginning of the arrow with the term - heredity potential. The ultimate form of the plant is determined by the amount and planes of cell division; the amount and direction of cell enlargement; and the nature of the cell wall and protoplast after cell differentiation.

The series of events giving rise to a mature plant is not dependent on the heredity potential alone but the activities of cell division, enlargement and differentiation are modified by numerous factors both internal and external.

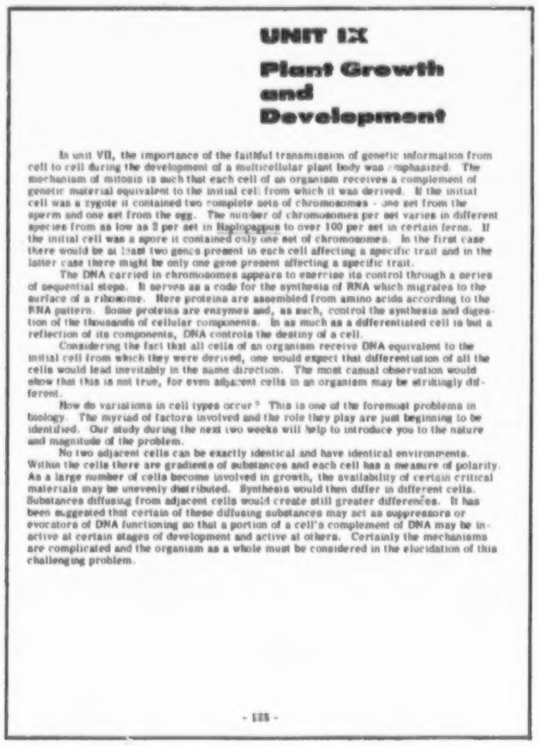
At the top of the chart is a list of some of the external factors in five major columns. Column 1, climatic factors, column 2, biotic, column 3, edaphic, column 4, gravity and column 5, pressure.

Column 1 - climatic factors include: a. light - intensity, quality, and periodicity. b. temperature, c. atmosphere - wind, humidity, composition. Column 2 - biotic factors: a. social, b. nutritive. Column 3 - edaphic: a. soil structure, b. mineral salts, c. water. No sub-factors are listed under columns 4 and 5. At the bottom of the chart are listed the internal factors in 4 columns. Column 1, water, Column 2, food, Column 3, minerals, and Column 4, growth substances. Under growth substances are listed: a. auxins, b. gibberellins, c. vitamins, d. inhibitors.

Note the arrows drawn from each column toward the terms cell division, enlargement and differentiation, to indicate that each of these factors may exercise some control over these events and consequently influence the ultimate form of the individual.

As you can see from the diagram, the study of growth is a very complex one. It requires that one set up experiments in which only one factor is varied but an interpretation of results of such an experiment must take into account the impact of this variation on the many other factors influencing growth.

Study the introductory paragraphs to plant growth and development in the study manual, page 105 - bong!!



UNIT IX

Plant Growth and Development

In unit VII, the importance of the faithful transmission of genetic information from cell to cell during the development of a multicellular plant body was emphasized. The mechanism of mitosis is such that each cell of an organism receives a complement of genetic material equivalent to the initial cell from which it was derived. If the initial cell was a zygote it contained two complete sets of chromosomes - one set from the sperm and one set from the egg. The number of chromosomes per set varies in different species from as low as 2 per set in Haplopappus to over 100 per set in certain ferns. If the initial cell was a spore it contained only one set of chromosomes. In the first case there would be at least two genes present in each cell affecting a specific trait and in the latter case there might be only one gene present affecting a specific trait.

The DNA carried in chromosomes appears to exercise its control through a series of sequential steps. It serves as a code for the synthesis of RNA which migrates to the surface of a ribosome. Here proteins are assembled from amino acids according to the RNA pattern. Some proteins are enzymes and, as such, control the synthesis and digestion of the thousands of cellular components. In as much as a differentiated cell is but a reflection of its components, DNA controls the destiny of a cell.

Considering the fact that all cells of an organism receive DNA equivalent to the initial cell from which they were derived, one would expect that differentiation of all the cells would lead inevitably in the same direction. The most casual observation would show that this is not true, for even adjacent cells in an organism may be strikingly different.

How do variations in cell types occur? This is one of the foremost problems in biology. The myriad of factors involved and the role they play are just beginning to be identified. Our study during the next two weeks will help to introduce you to the nature and magnitude of the problem.

No two adjacent cells can be exactly identical and have identical environments. Within the cells there are gradients of substances and each cell has a measure of polarity. As a large number of cells become involved in growth, the availability of certain critical materials may be unevenly distributed. Synthesis would then differ in different cells. Substances diffusing from adjacent cells would create still greater differences. It has been suggested that certain of these diffusing substances may act as suppressors or evocators of DNA functioning so that a portion of a cell's complement of DNA may be inactive at certain stages of development and active at others. Certainly the mechanisms are complicated and the organism as a whole must be considered in the elucidation of this challenging problem.

- 105 -

During this inquiry we will be using some important terms, some with which you are already familiar. Perhaps it would be helpful to begin with the definition of a few of these. The first term is growth. Growth is an irreversible enlargement of cells. It involves the synthesis of raw material and the assimilation of this new material into the components of the cell. On an organismal basis it may include to some degree all three of the basic events, cell division, cell enlargement and cell differentiation.

The second term is coleoptile - you are already familiar with the term coleoptile but I would like to remind you that this is a modified leaf which is found in the grasses. It is at the second node just above the cotyledon and it is a leaf which is cone shaped and encloses all of the other leaves of the young grass seedling until such time that the seedling emerges from the soil and the enclosed leaves penetrate the enclosing coleoptile. Because the coleoptile does most of its cell division in the early stages of its formation and during the latter stages only cell enlargement occurs, it has provided us with a very sensitive unit for measuring small amounts of growth substances which effect cell elongation as you will see a little bit later when we discuss the work of Dr. Went.

The third term we would like to discuss is growth factors or growth substances. These substances are controlling agents which enter the cell and influence the activities related to growth. This term includes essentially all of the substances which influence growth. There might be included here such things as mineral substances, although minerals have other effects than the one inferred when we speak of growth factors - vitamins, auxins, gibberellins and kinins. I will spell some of these words for you: vitamins, v-i-t-a-m-i-n-s, auxins, a-u-x-i-n-s, gibberellins, g-i-b-b-e-r-e-l-l-i-n-s, and kinins, k-i-n-i-n-s.

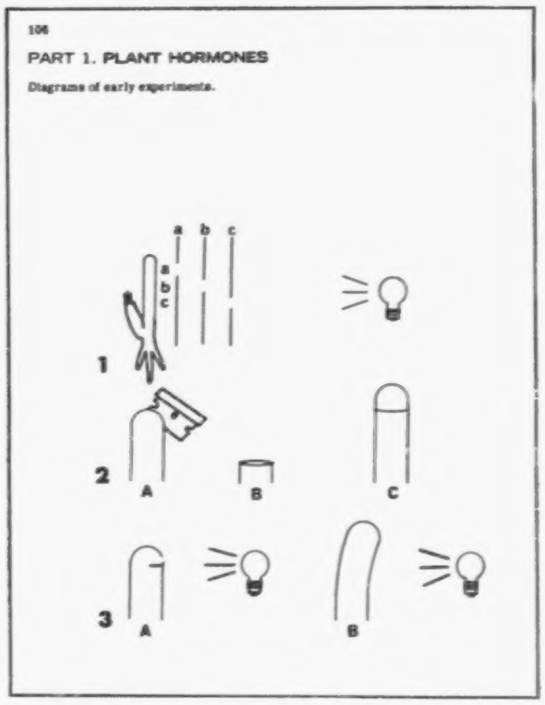
The fourth substance or term is the term hormones, and since we are talking about plants, we would be discussing phytahormones, p-h-y-t-a-h-o-r-m-o-n-e-s, phytahormones. A hormone is a controller or growth substance produced in one part of the plant and is transported or translocated to another part of the plant where it exerts its effect. It is effective in a very small quantity.

The fifth term is growth regulator. A growth regulator is a controller of growth or growth substance which is obtained from external environment.

Perhaps it is best to develop our study somewhat historically for this study of plant science is a relatively young one.

Turn to page 106 in the study manual and locate comparable diagrams in your text. Place these before you to help visualize some of the early experiments performed in learning about plant hormones.

At this point the student would open his text and turn to page 106 in his study manual (see below) and refer to the diagrams while he listened to the discussion on the tape. Whenever he desired he would stop the tape to take notes or replay portions as necessary to complete his understanding.



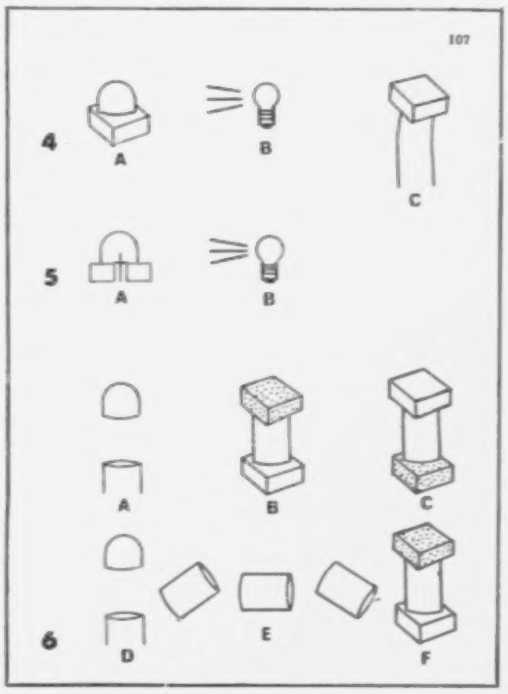
106

PART 1. PLANT HORMONES

Diagrams of early experiments.

The story begins with experiments of Darwin in 1880 in which he was attempting to determine how light influences the turning of a plant. He was actually looking for the receptor in the plant or just exactly what area of the plant is able to receive the light. He was looking for something like an eye photoreceptor such as we find in animals. Diagram 1, page 106 illustrates this kind of experiment. To the left is a diagram of an oat seedling and three locations are identified on the coleoptile as a, b, and c. The actual area in which the turning takes place is in location c. To determine whether or not this is the region in which the light is received one could shield the coleoptile with one of a series of cloths (a, b, and c) containing windows which would allow the light to be received at specific areas on the coleoptile tip. When the cloth (a) is used, light strikes the coleoptile at (a). When cloth (b) is used, light strikes the coleoptile at (b) and when cloth (c) is used, light strikes the coleoptile at (c). There is no turning of the coleoptile tip toward the light when the light strikes the coleoptile at (b) or (c), but when the window is placed before the region (a) so the light falls on the very tip of the coleoptile soon thereafter the coleoptile begins to bend toward the light and the region of the bending, of course, is in region (b) and region (c). Darwin was at a loss to explain why the plant turned toward the light even though he had located the region which was receptive to light. It remained for some experiments to be done considerably later which gave us some idea of how this movement may occur. If one were to cut off the coleoptile tip as we show in diagram 2A leaving the stump at (b), the stump will not elongate any more or at least only a small amount whereas, if one cuts off the tip and then replaces it as shown at (c), the coleoptile stump will elongate for a short time as if no cutting had been done. Diagram 3 illustrates that a piece of mica or other impermeable material inserted on the lighted side of a coleoptile and just below the light sensitive area will not prevent bending of the coleoptile toward the light. In contrast, mica inserted similarly on the shaded side of the coleoptile will prevent turning toward the light.

How might one interpret such results? Does the plant response involve nerve cells? Severing nerve connections between the receptor (a) and the location of the response (c) should prevent any nerve dependent reaction. What does the illustration at 2 suggest in this regard? Replacement of the coleoptile restores the ability to elongate; therefore, some substance produced in the apex (a) must be able to move across the juncture between the coleoptile apex and its stump. From the illustrations in diagram 3 it is implied that the substance hypothesized from diagram 2 must accumulate on the shaded side of the coleoptile and move to location (c) and there cause the bending reaction.



Turn now please to page 107.

The student would turn his attention to the diagrams on page 107 in the study manual.

The illustrations in diagrams 4 and 5 represent experiments which vary slightly in design from those in 3 but essentially they confirm and elaborate the ideas learned in 3. Dr. Went (1928) showed that the substance produced in the tip of the coleoptile can be collected in agar blocks and that its distribution in the block corresponds to its distribution within the apex. The illustrations in diagram 4 indicate that an apex placed on an agar block (A) and irradiated with unilateral light (light from one side) (B) will impart to the agar block the substance so distributed that when the block is placed on a coleoptile stump (C), it will cause the stump to react as if it were an intact coleoptile receiving unilateral light.

It was apparent that some chemical substance must be produced in the apex of coleoptiles which became unevenly distributed under the influence of unilateral light and when the agar block was removed at the appropriate time, it contained this chemical substance in comparable concentrations to that of the original apex. Kögl and Haagen-Smit analyzed the substance and identified it as indoleacetic acid. Since it promoted cell elongation, it was called "auxin".

Dr. Went, through an ingenious application of his technique, devised a bioassay for growth substances involving the use of oat coleoptiles and agar blocks. The substance to be tested for growth activity was placed in a small agar block and the block placed on one side of a previously prepared coleoptile. The coleoptile was prepared by growing oat seedlings at a certain stage of development in red light and by removing the auxin producing apex. If the substance in the block had growth activity, the coleoptile would bend in direct relation to the amount of the substance present. The angle of curvature was taken as an index to the amount of activity of the substance. This test - because of its great sensitivity to small quantities of growth substances - became a standard test and is still used effectively in critical research with growth substances.

Diagram 5 illustrates an experiment which revealed that more auxin was produced on the shaded side of the stem than on the lighted side. An apex at "A" was situated so it rested on two agar blocks separated by an impermeable strip of mica. Unilateral light B was allowed to fall on the apex as shown and later the two blocks were tested for growth activity by the Went coleoptile technique. It was shown that the agar block on the shaded side of the apex contained more auxin than the agar block on the lighted side. What implications does this experiment have for the statement that a plant seeks light?

I would like for you to attempt an analysis of the illustration in diagram 6. The stippled blocks contain auxin.

Write out your explanation and check it with me in just a few moments - bong!!

At this point the student should study the diagram and attempt an interpretation. Having done this he would then turn on the tape and listen to the following explanation.

In diagram 6 the illustration at A represents a coleoptile with a segment removed. The segment is shown at B between 2 agar blocks, the top block contains auxin. The illustration at C shows the segment and blocks some time later and that the auxin has moved through the coleoptile segment from its top to its bottom. The illustration at D likewise shows a coleoptile with a segment removed but in this instance the segment (e) has been rotated so the base is up and the top is down. Note at F the auxin will not move through the coleoptile in this direction. In other words - the movement of auxin is polar - it moves away from the area in which it is synthesized.

There are several ideas which we should learn from the diagrams which will be helpful in the interpretation of demonstrations and experiments to be performed later.

1. A growth promoting substance called auxin (IAA) is produced in the apex or meristematic area of an organ.
2. This substance is translocated from its origin to other areas of the plant where it may affect growth - in other words the substance is a hormone - a plant hormone.
3. One action of a hormone is to make cells elongate - if cells on one side of an organ such as a stem, root, or coleoptile, elongate more than cells on the other side, the organ will be caused to bend.
4. Light results in the movement of auxin to the shaded side of the organ and destroys auxin on the lighted side. In stems this results in a turning toward the light.

The term for turning is tropism, t-r-o-p-i-s-m. Various stimuli may cause a turning or tropism. The name for the phenomenon of a turning is made by using an appropriate term for the stimulus as the prefix and using "tropism" as the suffix, e.g. if the turning is in relation to the source of light, the phenomenon is called phototropism - if the stimulus is gravity, the phenomenon is called geotropism - if the turning of the organ is toward the source of stimulus, it is a positive tropism and if it is away from the source of stimulus, it is a negative tropism.

I would like for you to study some experiments and demonstrations involving tropistic responses. Please turn to page 108 and 109 and do the exercises described. Study carefully the displays on the demonstration table - bong!!

At this point the student would go to the demonstration table (Fig. 4. 1) and with the study manual open to page 108 and 109 he would do the exercises and study the living plant material shown in Figure 4. 2.

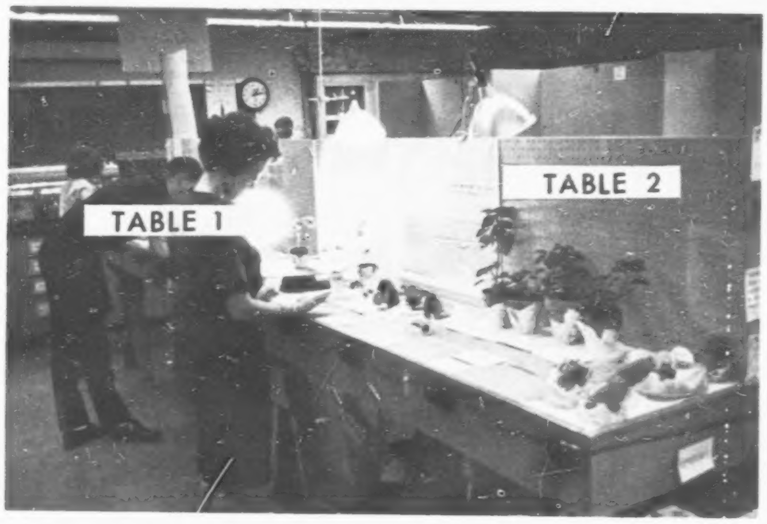
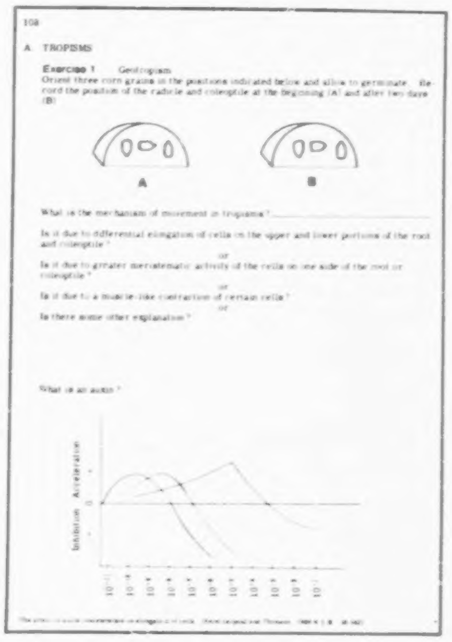


Figure 4. 1 - Demonstration tables showing the distribution of materials for student study.



108

A TROPISMS

Exercise 1 Geotropism
Orient three corn grains in the positions indicated below and allow to germinate. Record the position of the radicle and coleoptile at the beginning (A) and after two days (B).

What is the mechanism of movement in tropisms? ____________

Is it due to differential elongation of cells on the upper and lower portions of the root and coleoptile?

or

Is it due to greater meristematic activity of the cells on one side of the root or coleoptile?

or

Is it due to a muscle-like contraction of certain cells?

or

Is there some other explanation?

What is an auxin?

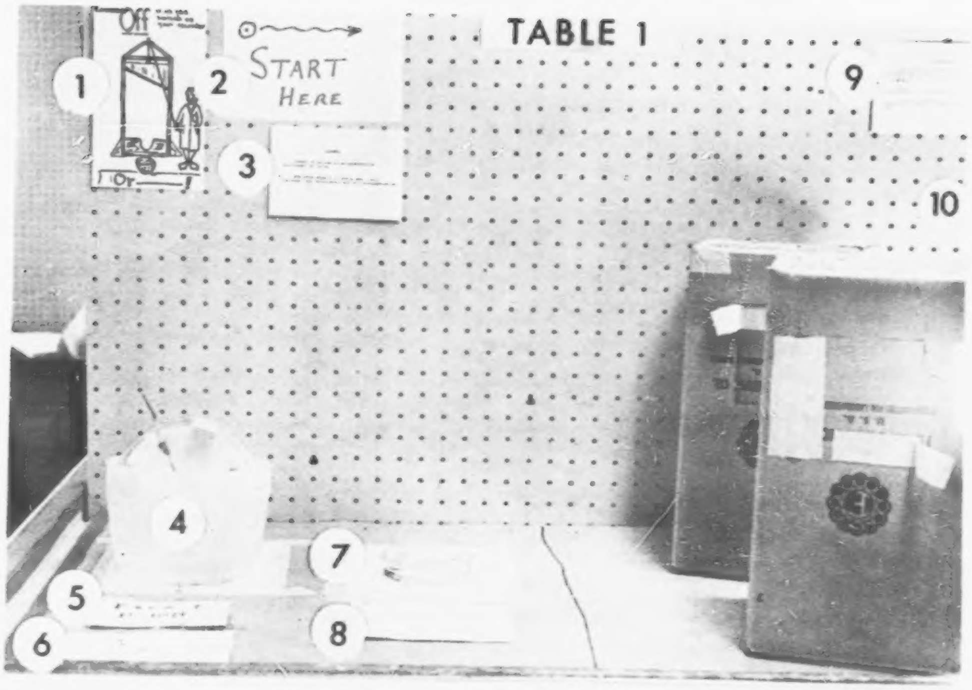


Figure 4.2 - 1. Sign. Remember, off with the switch on your recorder, or ——! 2. Sign. Start here. 3. Sign. Growth. Growth is defined as an irreversible enlargement of cells. The 3 aspects of growth are: cell division, cell enlargement, and cell differentiation. 4. Two large petri dishes taped back to back with filter paper and 4-day old corn seedlings between them. The 4 corn grains were each oriented a different way. The filter paper acts as a wick and dips down into a container of water. 5. Sign. Exer. 1, p. 108. 6. Sign. Geotropism. Note the direction of root growth and the direction of stem growth. Can you suggest a possible mechanism? 7. Petri dish containing a bean seedling. 8. Sign. This seed was planted upside down. Note the orientation of the epicotyl and the root. This is an example of geotropism.

On completion of this study the student would return to the tape and listen to a discussion of the other items on page 108 in his study manual. The discussion follows:

In exercise one you noted that the radicles turn down and the coleoptiles turn up regardless of the original orientation of corn grains. From the diagrams on pages 106 and 107 it was learned that the turning of an organ is due to differential elongation of cells within the organ and that the presence of auxin causes elongation of cells.

The mechanism of a tropism or turning then is differential elongation of cells within an organ in response to differential distribution of auxin. The auxin distribution is influenced in some way by an external stimulus.

The first listed interpretation is the correct explanation.

The stimulus - gravity causes auxin to accumulate on the lower side of the organ - radicle and coleoptile. How is it then that one turns down and the other turns up?

The effect of auxin on elongation of cells of roots, leaves, and stems is illustrated in the graph at the bottom of page 108. The lines represent from left to right (and I suggest you label them) 1st line - roots, 2nd line - buds and 3rd line - stem. Using this information, can you now explain why the radicle turns down and the coleoptile turns up even though both have a higher concentration of auxin on their lower side? According to the graph what range of concentration of auxin would result in inhibition of cells in the root but be stimulating in the stem? Auxin must be present for elongation of cells in either root, bud or stem. What range of concentration of auxin accelerates root cell elongation?

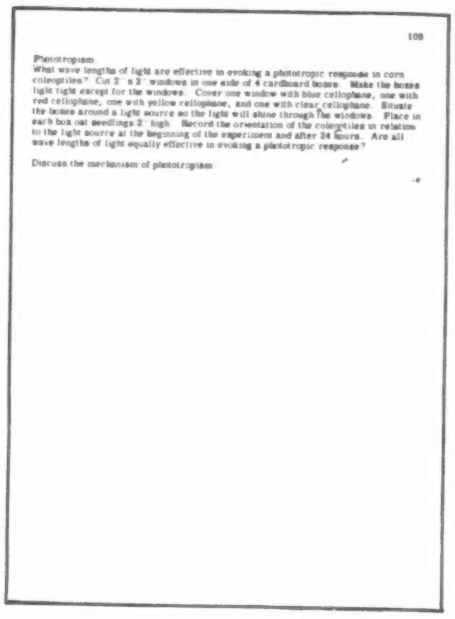
What range accelerates bud cell elongation?

What range accelerates stem cell elongation?

Root cell elongation is accelerated in auxin concentrations from approximately 10^{-11} to 10^{-8}; buds from 10^{-10} to 10^{-7}; and stems from 10^{-10} to 10^{-3}.

The questions on pages 109 and 110 are all answerable from observations of the experimental setup and from the preceding discussions. Go to the demonstration table and make observations on the experimental setups. Answer all questions posted behind each setup. - Bong!!

The student would now go to the demonstration table and study materials shown in Figures 4.3, 4.4, 4.5 and 4.6, using pp. 109 and 110 in the study manual. The instructor on duty would give assistance if required by the student. On completion of this study the student would return to the tape for further instructions.

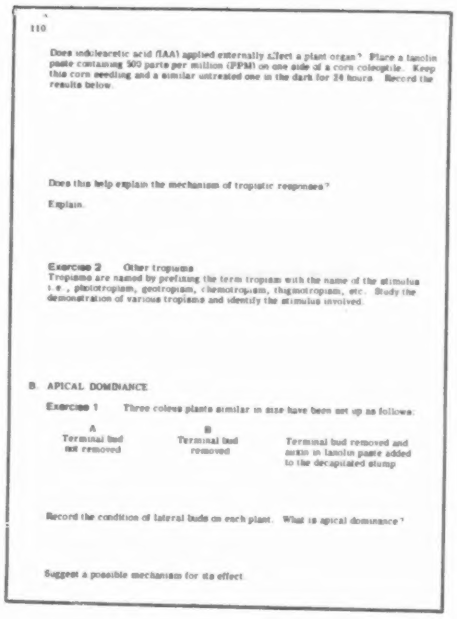


109

Phototropism

What wave lengths of light are effective in evoking a phototropic response in corn coleoptiles? Cut 2" x 2" windows in one side of 4 cardboard boxes. Make the boxes light tight except for the windows. Cover one window with blue cellophane, one with red cellophane, one with yellow cellophane, and one with clear cellophane. Situate the boxes around a light source so the light will shine through the windows. Place in each box oat seedlings 2" high. Record the orientation of the coleoptiles in relation to the light source at the beginning of the experiment and after 24 hours. Are all wave lengths of light equally effective in evoking a phototropic response?

Discuss the mechanism of phototropism.



110

Does indoleacetic acid (IAA) applied externally affect a plant organ? Place a lanolin paste containing 500 parts per million (PPM) on one side of a corn coleoptile. Keep this corn seedling and a similar untreated one in the dark for 24 hours. Record the results below.

Does this help explain the mechanism of tropistic responses?

Explain.

Exercise 2 Other tropisms

Tropisms are named by prefixing the term tropism with the name of the stimulus i.e., phototropism, geotropism, chemotropism, thigmotropism, etc. Study the demonstration of various tropisms and identify the stimulus involved.

B. APICAL DOMINANCE

Exercise 1 Three coleus plants similar in size have been set up as follows:

A	B	
Terminal bud not removed	Terminal bud removed	Terminal bud removed and auxin in lanolin paste added to the decapitated stump

Record the condition of lateral buds on each plant. What is apical dominance?

Suggest a possible mechanism for its effect.

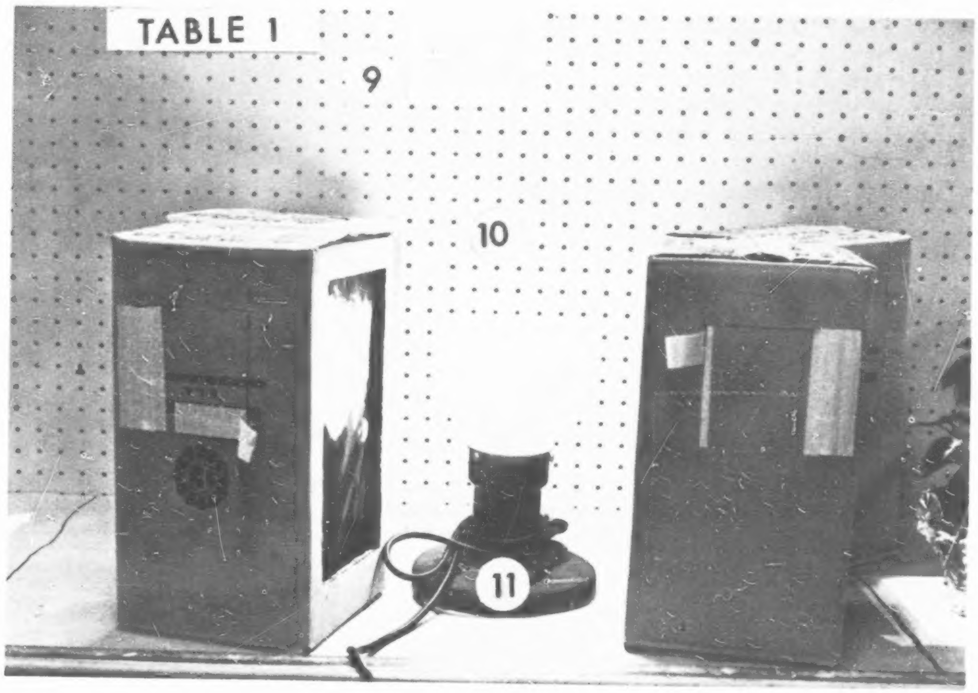


Figure 4.3 - 9. Sign. Phototropism. The plants below have been subjected to different wave lengths of light. Observe the directions of growth of each plant in relation to the position of the light. What color of light is responsible for stimulating a positive phototropism? Suggest a possible color for the pigment absorbing the light. What pigment might this be? 10. Four cardboard boxes, each containing a 2-week old kidney bean plant. Each box has had one side cut out and replaced by a piece of cellophane--red, blue, green, or clear. Each box also has a small observation door cut into it. 11. Light

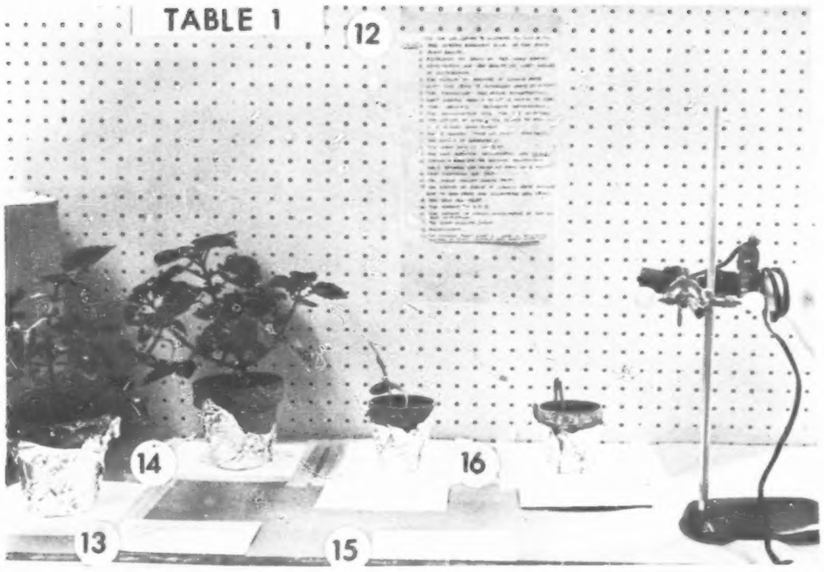


Figure 4.4 - 12. Copy of lab oral quiz guide sheet. 13. Sign. A lanolin paste containing 500 ppm IAA was applied to the petioles and stems at various places. Observe the effects of the applications. Suggest a possible mechanism, and explain your answer. What function does lanolin play? What is used as a control? 14. One Coleus plant treated with lanolin-IAA, the other with plain lanolin. 15. Sign. The effects of IAA on corn coleoptiles. 16. Sign and Plants. One corn plant treated with lanolin-IAA, the other with plain lanolin.

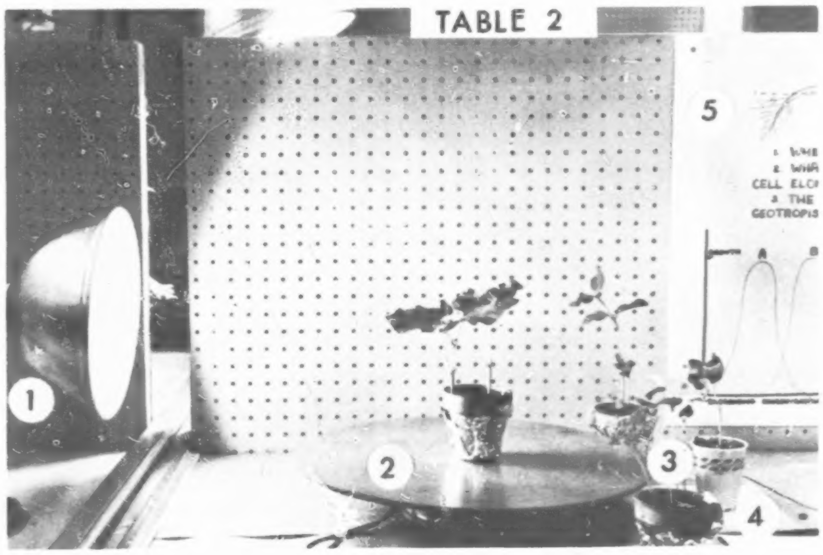


Figure 4.5 - 1. A ringstand and light. 2. An electrically powered revolving turntable with a 2-week old kidney bean plant placed in the center. 3. Pots of 2-week old soybeans, kidney beans, and buckwheat. 4. Sign. Phototropism. Why do these plants bend toward the light? Will the plant on the revolving turntable bend toward the light?

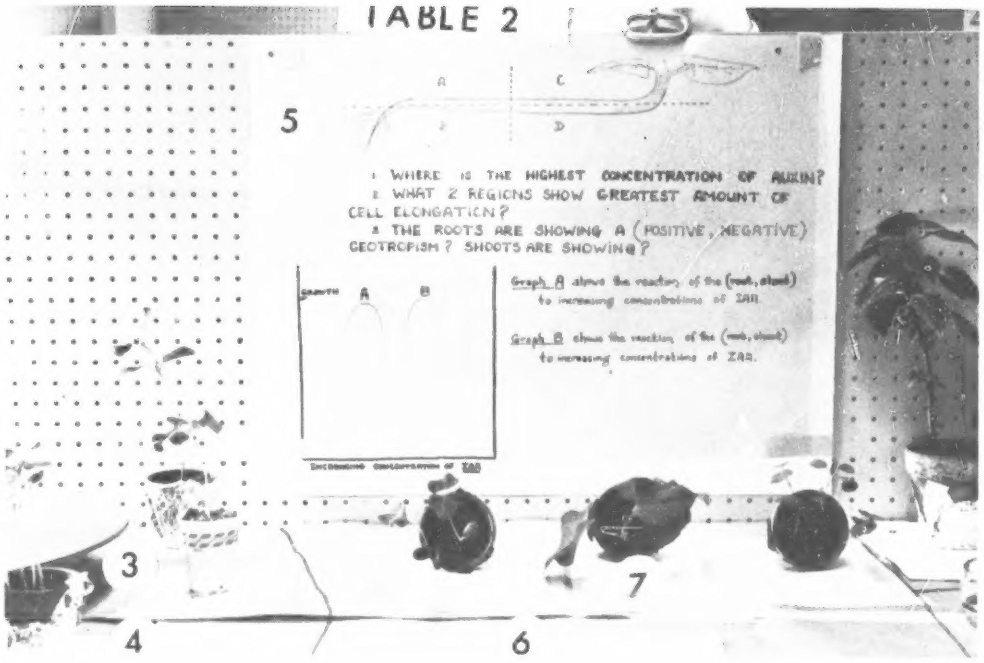


TABLE 2
5
A
C
B
D
1 WHERE IS THE HIGHEST CONCENTRATION OF AUXIN?
2 WHAT 2 REGIONS SHOW GREATEST AMOUNT OF CELL ELONGATION?
3 THE ROOTS ARE SHOWING A (POSITIVE, NEGATIVE) GEOTROPISM? SHOOTS ARE SHOWING?
GROWTH
A
B
INCREASING CONCENTRATION OF IAA
Graph A shows the reaction of the (root, stem) to increasing concentrations of IAA.
Graph B shows the reaction of the (root, stem) to increasing concentrations of IAA.
3
4
6
7

Figure 4.6 - 5. Poster illustrating geotropism. 7. Pots of soybeans, kidney beans, and buckwheat lying on their sides. 6. Sign. Will there be root growth at the optimum concentration of IAA for stem elongation?

Now do exercise 1 under paragraph B, pp. 110 - apical dominance. Bong!!

Most of the instructions for doing this exercise are in the laboratory manual. The student would use his manual and the materials provided on the demonstration table shown in Figure 4.7, to complete this exercise.

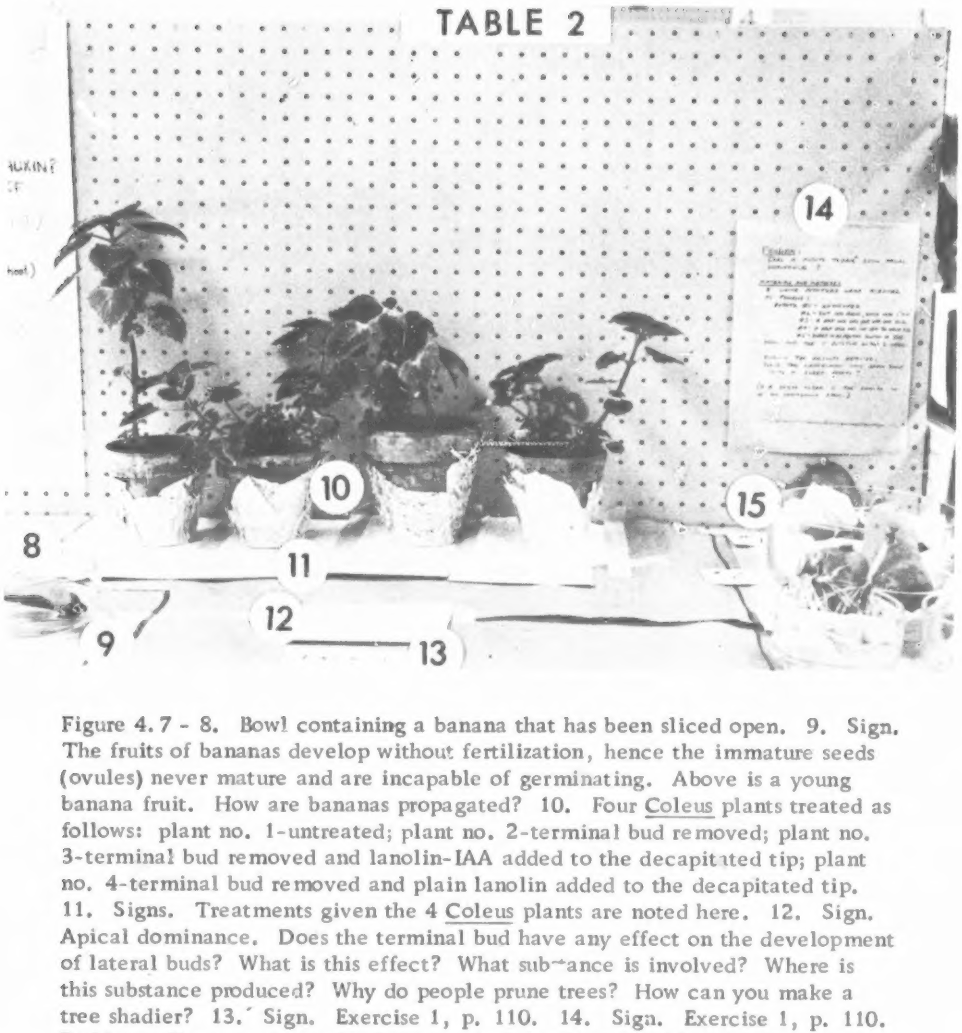


Figure 4. 7 - 8. Bowl containing a banana that has been sliced open. 9. Sign. The fruits of bananas develop without fertilization, hence the immature seeds (ovules) never mature and are incapable of germinating. Above is a young banana fruit. How are bananas propagated? 10. Four *Coleus* plants treated as follows: plant no. 1-untreated; plant no. 2-terminal bud removed; plant no. 3-terminal bud removed and lanolin-IAA added to the decapitated tip; plant no. 4-terminal bud removed and plain lanolin added to the decapitated tip. 11. Signs. Treatments given the 4 *Coleus* plants are noted here. 12. Sign. Apical dominance. Does the terminal bud have any effect on the development of lateral buds? What is this effect? What substance is involved? Where is this substance produced? Why do people prune trees? How can you make a tree shadier? 13. Sign. Exercise 1, p. 110. 14. Sign. Exercise 1, p. 110. Problem: Does a potato tuber* show apical dominance? Materials and Methods: 5 white potatoes were treated as follows: potato #1-untreated, #2-cut into pieces, each with one "eye", #3-a half inch was cut off one end, #4-a half inch was cut off the opposite end, #5-dipped in an aqueous solution of IAA. Here are the 5 potatoes after 2 weeks. Explain the results obtained. Could the experiment have been done with a sweet potato? (*A tuber is the swollen tip of an underground stem.) 15. Five bowls, each containing a potato.

Having completed the exercise the student would return to the tape to listen to a discussion about the experiment. The discussion follows:

In an intact plant - A - where the terminal bud is undisturbed - lateral buds are inhibited. The terminal bud in some way dominates the growth of buds lower on the stem. When the terminal bud is removed (B), the inhibition is removed and the buds begin to grow. Substitution of auxin for the terminal bud restores the dominating effect on the lower buds. Since the apex is a location in which auxin is synthesized, this experiment strongly suggests that the auxin produced by the terminal bud brings auxin to an inhibitory level in the region of the lower buds and the mechanism of apical dominance is merely a control of auxin concentration. This is a good example of hormonal control.

Perhaps variation of this mechanism may account also for the characteristic excurrent shape of pine trees, the deliquescent shape of elm trees, and the columnar shape of palm trees. The growth and development of an organism can be in part, accounted for by the action of some of the substance discussed in the beginning of this study. Before you continue your laboratory experiments, I would like to discuss in more or less lecture fashion certain aspects of growth.

In recent years there have been no giant strides in investigating these substances; however, there has been a continuous stream of investigations which have been very helpful; there still is a lot we need to know, but a lot has been done. There has been a careful analysis of certain of these growth substances and an investigation for potential growth activity induced by compounds of like-structure and these studies have revealed that there are a large number of compounds which may be classed as growth factors or growth substances. There are certain characteristics or certain configurations of the molecules of these substances which are very suggestive of the type of action in which they may be involved in the plant; however, no clear cut explanation has been arrived at as yet.

For the moment, let me remind you that all of the activities within a cell are ultimately controlled by genetic information located on chromosomes within the cell. The unit of this material which controls one heritible character or trait of an individual is called a gene. The chemical compound which appears to occupy the role of the pattern or templet is called deoxyribonucleic acid or DNA, and this substance we have already mentioned and you are already familiar with it. You will remember in our study of cells, we said that the DNA molecule served as a pattern for the production of messenger RNA and that the messenger RNA moved from its nuclear location to ribosomes, and there it dictates the linking together of amino acids into proteins which are important in imparting characteristics to the cell. In other words, the cell owes its peculiarities or its character to the kinds of protein compounds that have been formed in response to the dictates of the DNA. Since an organism is constituted of many such cells and since the action of a specific gene might be stimulated by the presence of appropriate hormones, a hormone control system must regulate the development and activity of an individual organism and its parts. Thus a group of cells may function essentially as a unit, behaving in an integrated way, that is, each cell functioning individually, but its activity coordinated by the presence of one or more growth factors appropriately balanced or in proper proportion to result in a characteristic way of growth or development.

The hormone control system in a plant is a product of a series of progressive and coordinated changes resulting during the growth and development of the organism from a zygote through its ontogenic stages. This series of events from the zygote to the mature plant results in the formation of various hormones at different times and these hormones, being located in different areas, moving to different areas, and accumulating there elicit from the cells a response which results in differentiation or specific adaptation of that area to its function. All of this is coordinated with the other parts of the organism. To say this in another way, I would like to call your attention again to the diagram in the booth. Let us discuss it again in the light of information we have just learned. The cell develops into the mature organism which we see to the extreme right through certain specific cellular phenonoma, that is cell division, cell enlargement and cell differentiation--these three basic steps, the general size and shape of this organism is going to be dependent on the duration and orientation of the various cell divisions, the duration and orientation of the cell enlargements, and the specialization or changes that occur in the cell wall and the protoplast of the cell--changes which we call differentiation. These three steps are under the control of the hereditary potential of the cell, that is, the DNA complement of that cell essentially dictates how and how much of these things are going to occur. But there impinges on these three steps a number of other factors which we have indicated at the top, the external factors of climate, biotic and adaptive factors, gravity and pressure, all of the aspects of light, temperature and the atmosphere will have their effect superimposed on this heredity potential along with the social, nutritive, biotic factors, and then the various soil factors. So external factors will effect the duration or orientation of cell division, the duration-orientation of cell enlargement and the changes in the protoplast and the cell wall at maturity. These factors cannot be ignored. The hereditary potential expresses itself in the background of these influences. Of course, within the developing plant there are various internal factors which we have indicated in the lower part of the diagram, such factors as water, foods, the amounts of water and food present, certain minerals, the auxins, gibberellins, vitamins, inhibitors and kinins -- all are substances which affect cell division, cell enlargement and cell differentiation. One of these, the kinins, hasn't been demonstrated as being a natural component of plants as yet but the effect of these substances seems to indicate that when we develop the adequate technique, we may discover that they are indeed a natural component of plants.

Since all of these factors play a role in growth and development, I think you can see that a study of growth and development becomes a very complex and involved investigation. Perhaps parts of this will be clearer as we study some specific examples and you may want to take some notes just now. Let us consider plant movements. Some texts divide plant movements into two categories, that is plant movements which are induced by the external environment and plant movements which are induced by internal stimili. Plant movements essentially all result from growth. There are some exceptions to this which we will note in just a few moments. Let us consider first those movements which are produced by internal stimili -- sometimes referred to as autonomic or spontaneous movements. If you were to place a camera immediately above a growing plant and then take a series of photographs at regular intervals, you would see that the plant does not grow straight up but grows in somewhat a circular type of movement. Place cartridge 1 in the 8 mm movie projector and observe this movement speeded up through time lapse photography. Bong!!

The student would now place a continuous loop cartridge-loaded film in a projector (ideally, the projector would be in his booth but could instead be located on the demonstration table) and observe growth movements as long as he desired (Fig. 4.8).

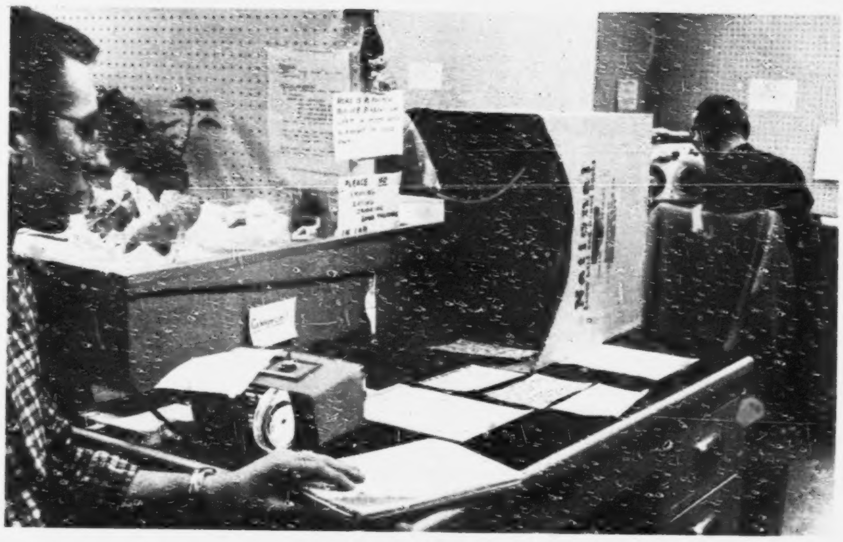


Figure 4.8 - Student viewing a short film. The film is a single loop cartridge loaded type and may be viewed as often and as long as he desires.

This circular type of movement is called nutation. Apparently there is some irregular diffusion of the auxin from the tip in which it is manufactured and this uneven flow of auxin down through the elongating region of the organ results in a swaying or circular movement called nutation. Study the demonstration material on Table 3. Bong!!

The student would turn off the tape and study items 1-5 located on Table 3 (Fig. 4.9 and 4.10).

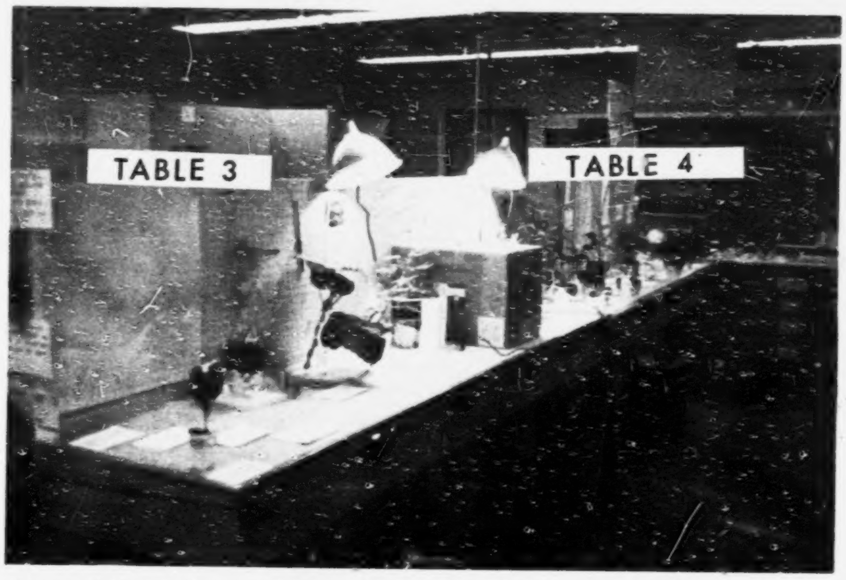


Figure 4.9 - A photograph of demonstration tables 3 and 4 showing the distribution of materials. Subsequent figures will show close up photographs of these materials.

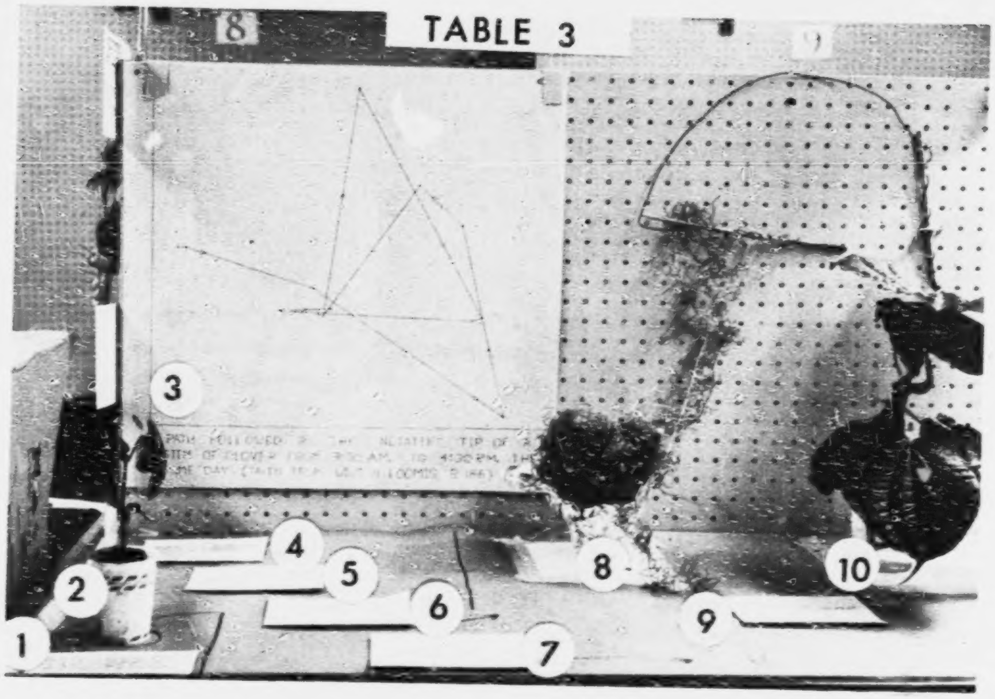


Figure 4. 10 - 1. Sign. A high concentration of unknown A (from problem 1) was put on the growing tip of this plant. The epicotyl died. Note that the lateral buds of the primary leaves and of the cotyledons are growing. Can you explain what has happened? Do you see why cotyledons are thought to be a type of modified leaf and are, hence, called seed *leaves*? (Further evidence may be obtained from the cotyledons of castor beans.) 2. Two-week old kidney bean plant treated with 3% phosphon in lanolin when it was 1 week old. 3. Poster showing the path followed by the nutating tip of a stem. 4. Sign. Plant movements are of two types: (1) spontaneous-the result of internal stimuli and relatively independent of the environment; and (2) induced-the result of a response to stimuli coming from outside the plant. Among the external stimuli causing plant movements are gravity, contact, shock, and fluctuations in light and temperature. Spontaneous movement: nutation. Induced movements: (1) tropisms, (2) nastic movements. 5. Sign. Nutation: The movement of a tip of a growing stem or other organ, describing an irregular path in space. 6. Sign. Tropism: A plant growth movement in which the direction of the movement is determined by the direction from which the stimulus comes. 7. Sign. Nastic movement: A plant movement in which the response is always the same and bears no relation to the direction from which the stimulus comes. 8. African onion showing its stems twining around a piece of wood. 9. Sign. Thigmotropism: Thigmotropism is a growth movement made by a plant in response to contact with a solid object. 10. *Dioscorea* (yam) showing one of its stems twining around another stem.

On completion of this study the student would return to the following discussion on the tape.

A second type of movement is due to the response of plants to external factors, one class of these we have discussed in adequate detail-i.e., tropisms. The term tropism means a turning and tropisms are responses of plants to a stimulus in relation to the direction of that stimulus or the source of that stimulus. Tropisms involve growth so there must be differential cell elongation which brings about this movement. If the cells on one side of an organ elongate more than the cells on the other side of that organ, this would result in a turning of that organ away from the side in which the cells elongated the most. Most tropisms are of this nature. We mentioned a while ago that light impinging on one side of a coleoptile tip brought about an unequal distribution of the auxin within the coleoptile so that on the shaded side of the coleoptile there was more auxin accumulated than on the lighted side. As a consequence the cells on the shaded side elongate more than on the lighted side and the tip of the plant then turns toward the light. A plant does not search for light then, but it turns toward the light in response to the differential distribution of auxin. The same thing is true with the response of plants to gravity.

The tropisms take on the name of the stimulus and are called phototropisms, geotropisms -- for example, a phototropism is a light tropism with the response of a plant to unilateral lighting and geotropism is a response of a plant organ to gravity, and then there are others such as chemotropism, hydrotropism, etc. Another kind of movement in response to external environment is called the nastic movement. A nastic movement is one in which the response of the plant is not in relation to the direction or source of the stimulus. Some very common nastic movements are the opening and closing of flowers, the folding of leaves at night, and the spreading of those leaves in the day time. This results from uneven growth. In the day time, the stimulus from light results in growth in the inside of the petal so that the flower tends to open and then at night the cells on the outside of the petals respond by greater elongation of growth. This results in the closing of the flower. The same seems to be true at least in part with the folding of leaves in the night time and the opening or spreading of those leaves during the day.

These movements for the most part are growth movements; however, some of this elongation may be reversible and consequently due to what we call turgor movements. The leaflets of the sensitive plant are normally all extended and held into position because of certain turgor relationships of cells at the base of each leaflet; however, with a sharp tap or other stimulus, the leaflets will tend to fold because of a movement of water out of the cells, actually a secretion of water out of the enlarged cells at the base of these leaflets, and the consequence of this is a shrinkage of certain areas of this structure and a folding of each leaflet. This movement is completely reversible, the plant recovers in a very short time and consequently these movements are referred to as turgor movements. Place cartridge 2 in the 8 mm movie projector and observe the time lapse movie of plant movements, then go to the demonstration table where nastic movements and turgor movements are demonstrated. Bong!!

The student would return to the demonstration table to observe items 6-18 in Figures 4.10, 4.11 and 4.12.

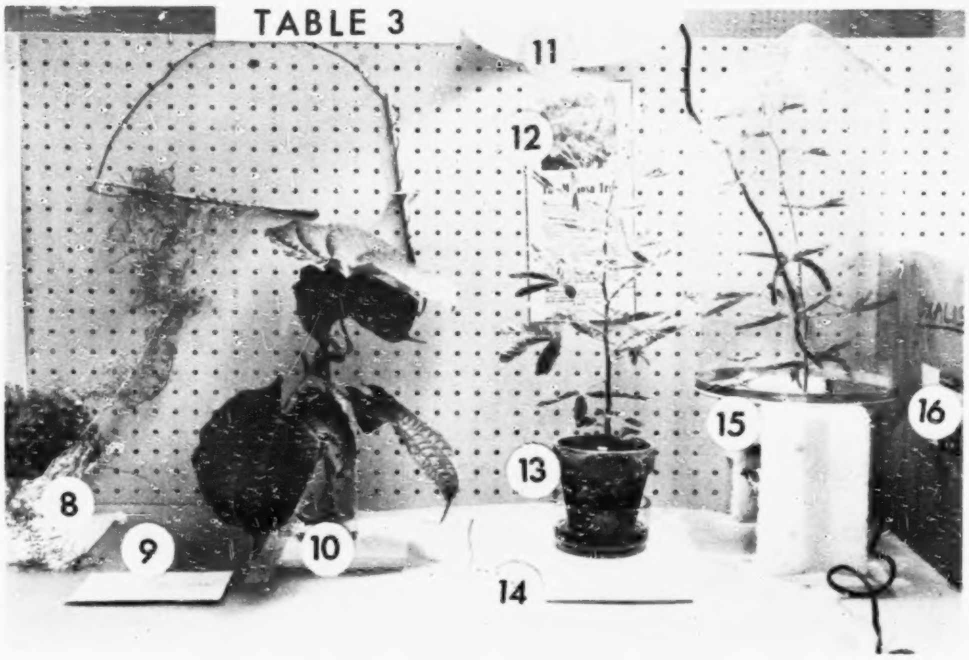


Figure 4.11 - 11. Light. 12. Newspaper clipping titled "The Mimosa Tree." 13. *Mimosa* for students to touch. 14. Sign. Thigmonasty. Note the response of the sensitive plant (*Mimosa*) to the touch of your finger.

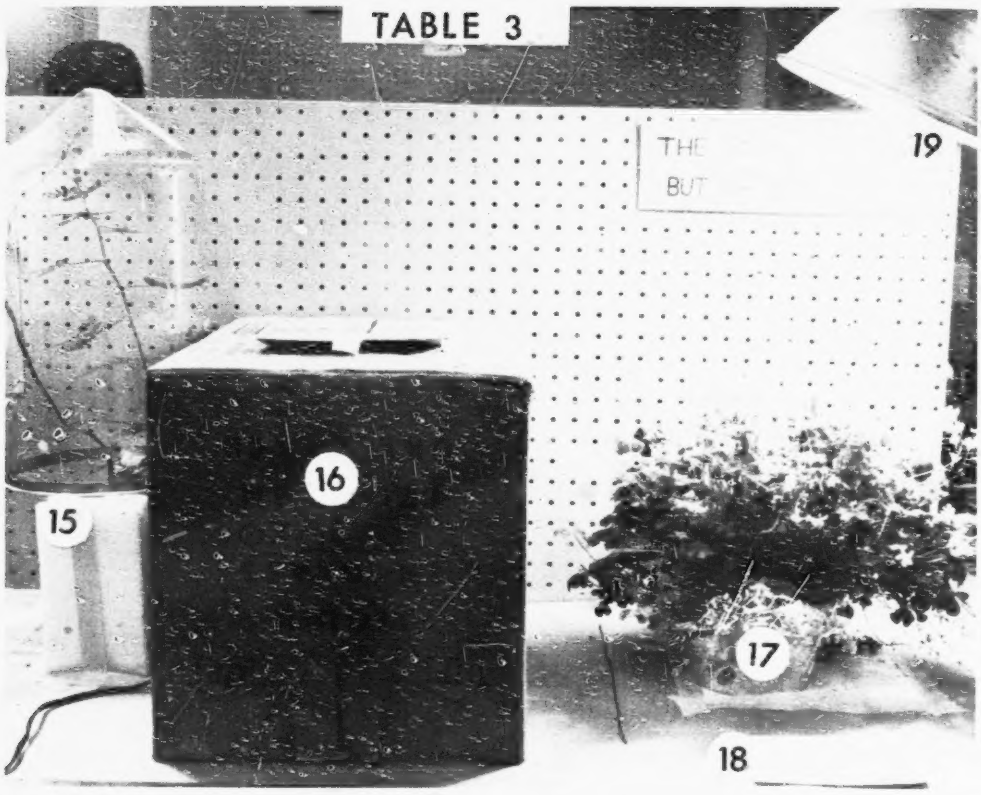


Figure 4.12 - 15. Mimosa shielded with a plastic cover to show the appearance of non-stimulated leaves. 16. Oxalis covered with a box. The box has a flap which can be raised so students can see inside. 17. Oxalis. 18. Sign. Photonasty. The leaves of the Oxalis droop at night. This nastic movement is often referred to as a "sleep movement." 19. Light.

On completion of study of the above materials, the student would return to listen to the following discussion on tape.

The movements we have just discussed are essentially all in response to a variation of the presence of auxin, a hormone. In recent years a number of other growth substances have been categorized in addition to auxins which have already been mentioned. I would like to take just a few moments to mention some more specific things about these. No. 1, mineral substances. Minerals, as you know, are components of many of the compounds which actually constitute the plant, however, they may be involved as catalysts or as coenzymes and their presence may be reflected ultimately in the size and composition of the plant, hence some botanists would suggest that we ought to include minerals as growth substances. The second group, the vitamins (and there are a number of vitamins) may also be categorized as hormones. Vitamins in general must act as coenzymes. A number of vitamins include such things as thiamin, and riboflavin. Riboflavin is concerned with aerobic hydrogen transfer. Another vitamin is nicotinic acid which serves as a precursor for DPN. Pantothenic acid seems to serve as a coenzyme A precursor. Then there are a number of acids associated with nucleic acid metabolism such as folic acid and vitamin B_{12}. Another vitamin called biotin is involved in hydrogen transfer as are vitamins C, D, E, and K. So, vitamins are necessary for plant growth. We do not hear much about the vitamins in plants because plants manufacture their own vitamins. There are some exceptions to this, of course, especially in certain of the fungi which require vitamins obtained from their host or the substrate in which they are growing.

Group no. 3 - the gibberellins, are growth promoting substances which have just recently been recognized as growth substances in the western world and have been investigated extensively by plant scientists because they seem to be associated with cell division and cell enlargement.

Gibberellin brings about elongation of internodes so that certain plants which tend to grow as a rosette when treated with gibberellic acid will develop elongated internodes and look much like other plants which have either a different genetic background or different habit of growth. I would like for you to see a demonstration of the effect of gibberellic acid. Will you go to the demonstration table, please, and observe plants treated with this substance. Bong!!

The student would now study items 1-3 shown in Figure 4.13.

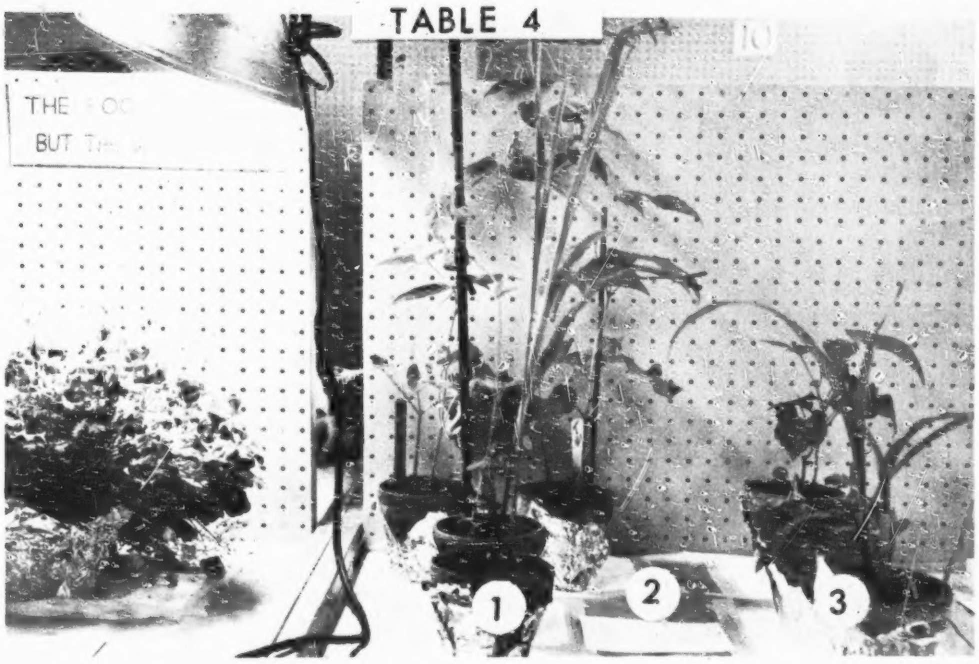


Figure 4.13 - 1. Four-week old corn, peas, and kidney beans previously treated with 1000 PPM gibberellic acid (K salt) dissolved in water plus 0.1% Tween 20. Several drops were put on the apex of each plant every other day during the second week of growth. 3. Untreated corn, peas, and kidney beans.

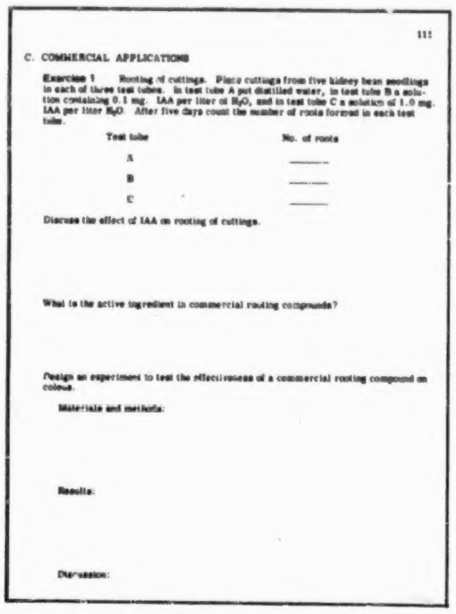
The student would return to listen to the tape.

A fourth group of growth substances which perhaps should not be included here, but we will for the moment anyhow, are the kinins, a group of substances which seem to effect cell division rather specifically. I have pointed out earlier that these substances have not been shown to be present in plants; consequently we are not really sure whether or not as yet they are an important growth substance in plants.

Another group of plant substances, no. 5, includes inhibitors, which instead of stimulating or promoting growth, actually tend to inhibit growth. Maleic hydrazide is an example of one of these. There are several others and just recently there have been discovered some new ones which show considerable promise in regulating flowering and other aspects of plant growth and development. One is 2-chloroethyltrimethylammonium chloride or the shorthand for this is CCC.

The sixth group of substances, that is, auxins, which we have already discussed at some length have been of considerable importance both from the standpoint of understanding growth and development, and from the standpoint of adapting it to commercial uses. Auxins seem to be involved in almost every step of growth or development of a plant and someone has likened the auxin effect as being somewhat analogous to rain falling on a garden with various kinds of seeds planted in the garden. The rain evokes a response of the seeds in various parts of the garden, and comparably, auxin tends to bring about responses of various kinds in the different parts of an organism. In each case these responses result in the proper kinds of development whatever it may be but auxin seems to be necessary for stimulating or initiating the action. Auxin is involved in the initiation of roots, the production of abscission layers (the layers which are formed between the stem and petiole of leaves which cause the leaves to drop in the fall), initiating the change from vegetative production to flower production by the apical meristem; they are involved in controlling the growth of lateral stems or buds; and a number of other things.

There are many synthetic chemicals which cause responses similar to the naturally occurring auxin and with investigation of these it has been found that several of them can be put to use commercially and applied to various agricultural practices. On pages 111 and 112 of your study manual, there is a series of exercises to emphasize some of the practical applications of growth substances. Do these exercises. Bong!!



111

C. COMMERCIAL APPLICATIONS

Exercise 1 Rooting of cuttings. Place cuttings from five kidney bean seedlings in each of three test tubes. In test tube A put distilled water, in test tube B a solution containing 0.1 mg. IAA per liter of H_2O, and in test tube C a solution of 1.0 mg. IAA per liter H_2O. After five days count the number of roots formed in each test tube.

Test tube	No. of roots
A	______
B	______
C	______

Discuss the effect of IAA on rooting of cuttings.

What is the active ingredient in commercial rooting compounds?

Design an experiment to test the effectiveness of a commercial rooting compound on coleus.

Materials and methods:

Results:

Discussion:

The student would study items 4-25 shown in Figures 4.14 and 4.15.

Figure 4. 14 - 4. Sign. IAA--indoleacetic acid. The "ever-present," "multi-purpose" plant hormone. This auxin is important in: (a) apical dominance, (b) leaf abscission, (c) fruit fall, (d) phototropism and geotropism, (e) rooting, (f) fruit development, (g) etc. 5. Sign. Plant hormones. Characteristics: (1) Produced in one part of the plant and used in another part. (2) Exert a marked effect on the metabolism and growth of the plant, probably acting as coenzymes. (3) Produced and used in small quantities. 6. Poster showing the similarities in structure between various growth regulators with auxin activity. 7. Three Coleus cuttings. 8. Sign. Two fresh Coleus cuttings were obtained. The end of one cutting was dusted with an auxin powder (Rootone). Both cuttings were placed in moist vermiculite for 1 week, then transferred to water for the 2 weeks before the lab. Both plants show initiation of adventitious roots. Determine which of the plants was treated with the hormone powder. What criteria can you use to determine your answer? Would this have any commercial value? 9. Sign. The concentration of auxin powder is not great enough to inhibit root growth. 10. Sign. All the leaves were removed from a fresh Coleus cutting. The cutting was then treated with hormone powder as in the above. Are adventitious roots initiated? In comparing this plant with the two cuttings in which the leaves were allowed to remain, what conclusions can you suggest concerning the influence of the leaves on root initiation? 11. Sign. Leaf abscission. The blades of several leaves were removed and lanolin-IAA (500 PPM) was applied to the ends of the petioles. Compare the treated plant with the control. What suggestions can you make concerning the influence of auxin on leaf abscission? 12. Treated and untreated Coleus plants.

Figure 4. 15 - 13. Graph showing the lengths of oat coleoptiles vs. concentration of IAA. 14. Sign. Avena straight growth test. Avena (oats) were germinated in the dark. Under red light the tips of the coleoptiles were removed and 10 mm. sections were cut from the decapitated coleoptiles. These sections were placed in a series of solutions containing known amounts of IAA. Once prepared, the solutions containing the 10 mm. sections were placed in the dark for 24 hours. The sections were then remeasured and the average lengths were plotted as a function of conc. of IAA. From what you have learned in lab, explain the results shown on the graph. Could the amount of IAA present in a plant extract be determined by this test? Explain. Would a similar curve be obtained for Avena roots? Explain. 15. Six dishes containing oat coleoptiles. Each dish contains a different conc. of auxin. The concentrations are 0 ppm, 10^{-2} ppm, 10^{-1} ppm, 10^{0} ppm, 10^{1} ppm. 16. Avena cutting tool and a paraffin block. 17. Sign. This is the type of cutting tool used to obtain sections of uniform length (10 mm) while removing the tip (the natural auxin source) at the same time. Avena Cutting Tool. 18. Sign. Ordinarily auxins are thought of as stimulators of cell elongation. One might think that they are also responsible for stimulating cell division, such as the formation of callus tissue or adventitious roots. Observe the various plants below treated with lanolin-IAA, and determine whether any evidence of cell division is present. What are your conclusions? 19. Two pots of kidney beans. In one pot 500 ppm lanolin-IAA has been smeared around parts of the stems to induce adventitious rooting. The plants in the other pot have been decapitated and the auxin paste applied to induce callus formation. The plants were treated two weeks before the lab. 20.. Poster showing the movement of growth substances in plants. The root hormone thiamin has been left off the chart as it has been included in the homework problems. 21. Sign. Reminder to students to keep the lab neat. 22. Sign. A problem involving the origin and movement of a growth substance is part of this week's homework. 23. Sign. Please observe the growth regulators display on the back table. 24. Dishes containing split pea stems placed in water and auxin solution (3 ppm IAA or NAA), respectively. 25. Sign. The split pea test for auxins and related growth substances. Pieces of pea seedling stems are slit longitudinally about three-fourths of their length. When placed in water the halves of the stems curve outward, but in auxin solutions they curve inward. The degree of curvature is proportional to the auxin concentration.

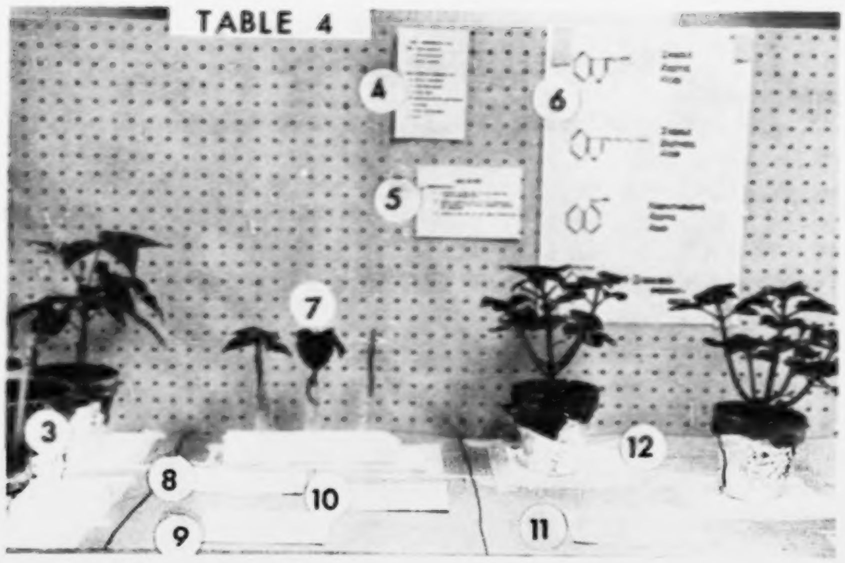


TABLE 4
4
5
6
7
3
8
9
10
11
12

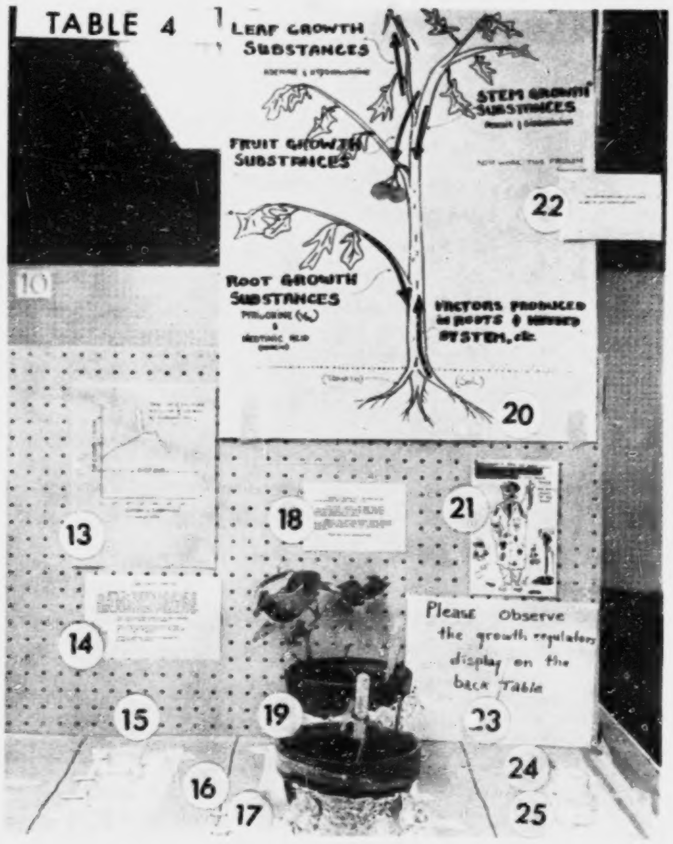


TABLE 4
LEAF GROWTH SUBSTANCES
STEM GROWTH SUBSTANCES
FRUIT GROWTH SUBSTANCES
ROOT GROWTH SUBSTANCES
FACTORS PRODUCED IN ROOTS & MOVED
SYSTEM, etc.
10
13
14
15
16
17
18
19
20
21
22
Please observe the growth regulators display on the back Table
23
24
25

On completion of this study the student would return to listen to the following taped discussion.

I would like to call your attention to some commercial applications of growth substances -- the first one, called 2,4-dichlorophenoxyacetic acid or 2,4-D for short, is a substance which some botanists suggest may occupy a position in a metabolic pathway which normally would be occupied by the natural auxin, and as a consequence of its competition for these metabolic substances it causes plants to grow abnormally and when applied in high enough concentrations will cause plants to die. It so happens that some of the plants, such as grasses, require a relative high concentration before they are inhibited or killed by this substance. As a consequence, it can be used as a selective weed killer, if one is attempting to kill broad leaf plants or dicotyledonous plants which are more sensitive than the grass.

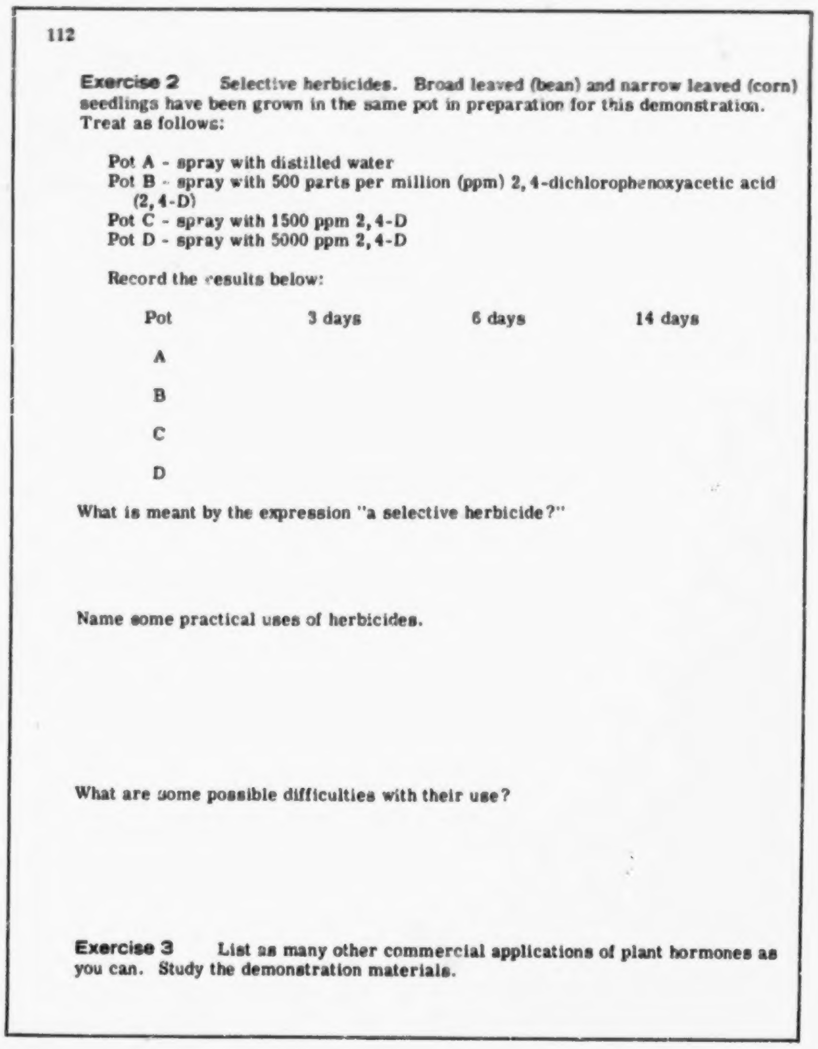
Another example of commercial application of these substances is the rooting of cuttings. It has been possible to use such things as indolebutyric acid and naphthyleneacetic acid, in various combinations on stems and twigs of various plants and induce these stems and twigs to produce roots where the attempts at rooting of these cuttings had failed previously. This, of course, has been of considerable use to the horticulturist. We mentioned a while ago that auxins affect the formation of abscission layers and consequently when certain of these materials are applied in the right concentration one can either induce formation of abscission layers or prevent the formation of abscission layers. So it has been feasible to apply certain of these substances to prevent fruit drop, also to apply them to cause leaves to absciss and fall from a plant. This has been important in the defoliating of cotton plants before the cotton is picked with the mechanical picker, also it has been useful in preventing abnormal fruit drop in certain varieties of our fruits where it is difficult to harvest these plants at a particular time. Apparently certain Christmas trees are treated to prevent the early loss of leaves after the trees have been cut prior to Christmas time.

Another commercial use has been that of controlling the dormancy of plants. In some instances the growth substances are used to induce dormancy so that plants do not begin their growth too early in the spring. In other instances, growth substances have been used to reduce dormancy or break dormancy, so that we can cause plants to grow that otherwise would not grow under these circumstances.

Other commercial uses of these substances include the improvement of fruit set and the ripening of fruit. Study the demonstrations on the various uses of these substances and complete the exercises on page 112 in the study manual.

On the next tape we will continue our study of plant growth and development.

This is all for this tape.



Exercise 2 Selective herbicides. Broad leaved (bean) and narrow leaved (corn) seedlings have been grown in the same pot in preparation for this demonstration. Treat as follows:

Pot A - spray with distilled water
Pot B - spray with 500 parts per million (ppm) 2,4-dichlorophenoxyacetic acid (2,4-D)
Pot C - spray with 1500 ppm 2,4-D
Pot D - spray with 5000 ppm 2,4-D

Record the results below:

Pot	3 days	6 days	14 days
A			
B			
C			
D			

What is meant by the expression "a selective herbicide?"

Name some practical uses of herbicides.

What are some possible difficulties with their use?

Exercise 3 List as many other commercial applications of plant hormones as you can. Study the demonstration materials.

The student would now study the experiments shown in Fig. 4.16 and the commercial growth substance display shown in Fig. 4.17.

TABLE 5

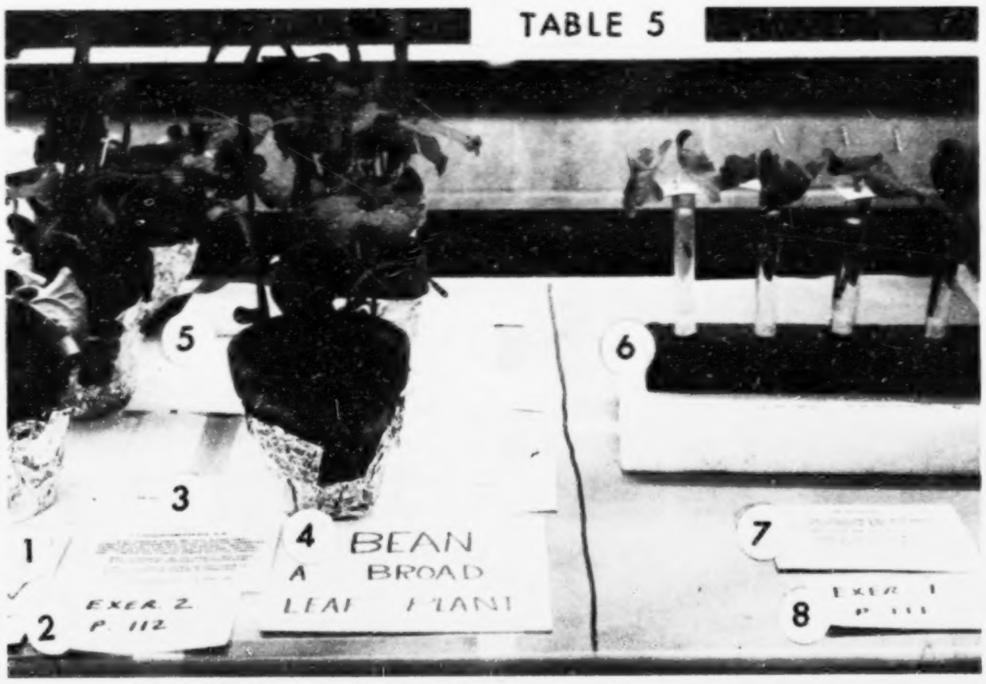


Figure 4.16 - 1. Sign. Corn. A narrow-leaved plant. 2. Sign. Exer. 2, p. 112. 3. Sign. 2,4-dichlorophenoxyacetic acid. Corn (narrow leaf) and kidney bean (broad leaf) plants were sprayed with 4 different concentrations of 2,4-D, a selective herbicide. The concentrations used were 10 ppm, 500 ppm, 1500 ppm, and 5000 ppm. Compare the treated plants with the control. What differences can you detect? Are there differences with different concentrations? Does 2,4-D have an effect on both types of plants? Does this suggest a commercial application? What is the action of 2,4-D when used in low concentrations? 4. Sign. Bean. A broad-leaved plant. 5. Pots containing both 2-week old kidney beans and corn. One pot was not sprayed. Each of the other pots have been sprayed with a different solution 3 days before the lab. The solutions were: water; 10 ppm 2,4-D; 500 ppm 2,4-D; 1500 ppm 2,4-D; 5000 ppm 2,4-D. 6. Four test tubes, each containing a bean cutting. The test tubes contain: pure water, 0.1 mg IAA, 1.0 mg IAA, and 10 mg IAA. The first three tubes show rooting. The tube with 0.1 mg IAA shows the most roots. No roots are produced in the tube with 10 mg IAA. The cuttings were started 2-3 weeks before the lab. 7. Sign. Root initiation. The roots of kidney bean plants were removed and the shoots placed in a series of solutions containing IAA. What effects are visible? Compare the concentrations with respect to root initiation and the continued growth of the adventitious roots. What conclusions can you make? Economic importance? 8. Sign. Exer. 1, p. 111.

WEEDING
CORN
PAD
WILD
GARLIC
CONTROL

Figure 4.17 - A display of growth substances which have been packaged commercially for use in controlling certain aspects of plant growth.

The student would now fill out page 112 in his study manual.

A notice in the booth will direct each student to set up a special experiment (Fig. 4.19) which was not included in the manual or the tape.

Sign in the booth:

NOTE: Do this experiment after completion of the tape.

Problem: Can the geotropic response of a stem be overcome or retarded by external applications of auxin?

Materials and Methods: The materials for this experiment are located on the cart in the prep room. Carry out the procedures as shown on the cart.

From what you have learned in lab, propose an explanation for your results.

Sign in prep room on the cart:

Materials and Methods

Select a cup containing at least three soybean plants. Using the applicator provided, apply a thin strip of lanolin-IAA five centimeters long from the tip down.

Place a similar strip on another plant except leave a one centimeter area exposed at the tip. In other words, start one centimeter below the tip and apply the strip of lanolin-IAA for five centimeters.

The third plant should serve as a control. A five centimeter strip of plain lanolin should be applied from the tip down.

If you have a fourth plant, you may apply the lanolin-IAA in any fashion.

Once you have finished the above procedures, take your plants and place them in a horizontal position on the shelf in the prep room so that the lanolin is on the uppermost side of the stems. Make sure your cup is labeled properly with your name and the treatments. You should return the next day and collect your data. Use only 1 cup.

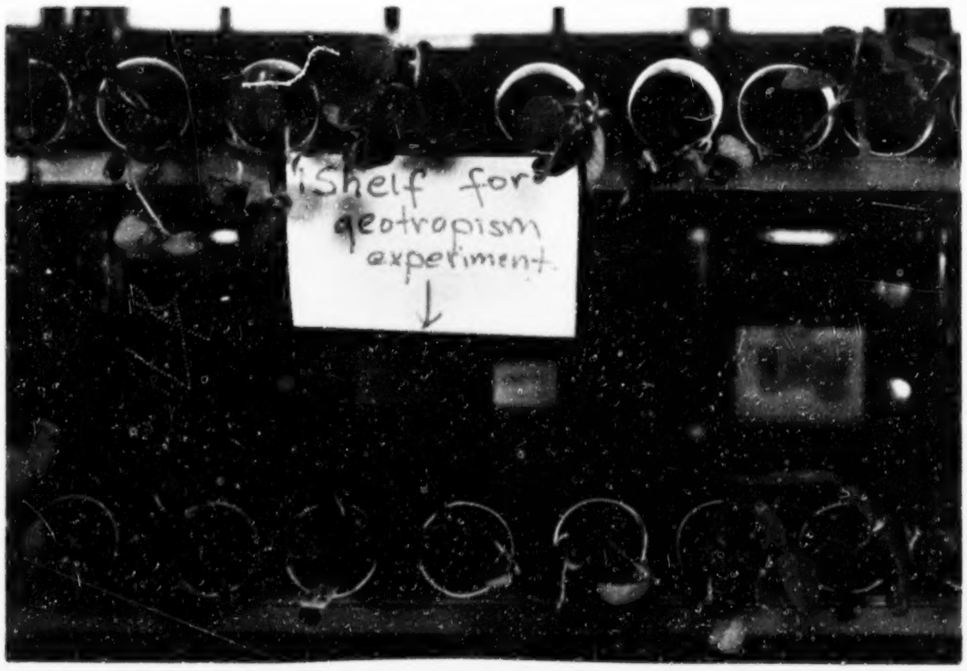


Figure 4.18 - A photograph of student-prepared experiments set up one day for examination at a later date. (Observation and collection of data need not conform to any schedule as is normally the case under the conventional system.)

When the student has completed the study, he may immediately present himself to the instructor for the ten point oral quiz; take practice quizzes from fellow students, self quiz machine or instructor; or repeat now or later any or all of the study and take his oral quiz as late in the week as Friday evening. The oral quiz will consist of a discussion of certain topics selected by the monitor from a posted list. The number of topics discussed will be at the discretion of the instructor and include the minimum number he feels is necessary to make a satisfactory evaluation of the student.

The General Assembly Session

The student would attend this session at a regularly scheduled time on Thursday or Friday. For this unit (Growth and Development) the authors use a guest lecturer. Dr. Marvin Schreiber discusses the very clever experiments he performs to discover the role of various environmental factors on growth and development of competing plant species. His presentation makes a smooth transition from the ecology unit covered the previous week to this week's subject matter. He shows how growth movements, availability of soil, water, and light, and application of growth substances as control measures affect development of plants. Dr. Schreiber summarizes by showing a time-lapse movie of his investigations, many scenes of which include striking views of plant movements during seedling growth.

The Home Study Session

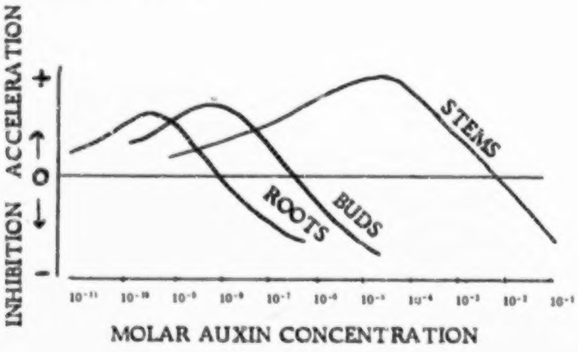
The student's home study is guided by a set of homework problems, text assignments and Scientific American articles assignments. The homework problems are picked up at the previous SAS and answers are either posted, mimeographed or otherwise made available to the student for checking his conclusions. He is encouraged to discuss his answers thoroughly with instructors, fellow students, and other knowledgeable people.

Homework problems for the first week's study on the unit of Growth and Development are as follows:

BIOLOGY 108 HOMEWORK PROBLEMS WEEK 1

1. A seedling plant which has sprouted and grown in the dark will have a dry weight which is actually less than that of the seed from which it was grown, although the volume of the seedling is far greater than that of the seed. A seedling sprouted and grown in the light will have a greater dry weight and volume than the seed from which it was grown. Explain these differences between the seeds and seedlings in terms of water absorption, digestion, respiration, photosynthesis, and growth.

2.



In each of the following, put down the nearest molar auxin concentration for your answer.

________ The highest auxin concentration shown on the graph.
________ The optimum auxin concentration for stem growth.
________ An auxin concentration that would have the least effect on stem growth and maximally inhibit bud and root growth.
________ The optimum concentration for stem growth is how many times too high for optimum root growth?
________ An auxin concentration that would stimulate stem, bud, and root growth.
________ The lowest auxin concentration that would maximally inhibit root growth.
________ An auxin concentration that would stimulate stem and bud growth but have no effect on root growth.

3. If a plant part, such as a root, is excised from the plant and is placed in a nutrient solution, it will grow naturally provided all the vitamins, hormones, etc. normally supplied by the whole plant are present. Table I is a record of an experiment involving this idea.

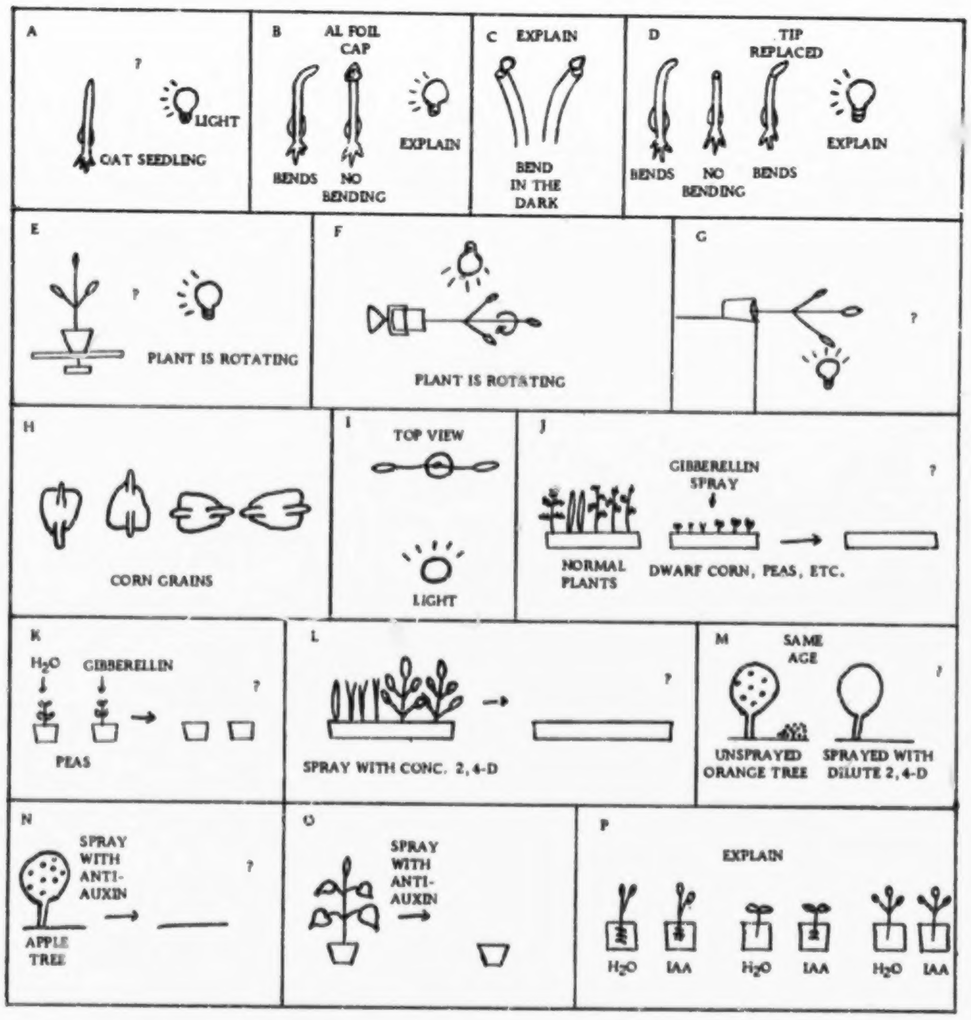
Root No.	Culture Solution	
	Without thiamin Growth (mm)	With thiamin Growth (mm)
1	1.0	10.1
2	0	11.0
3	0.5	9.8

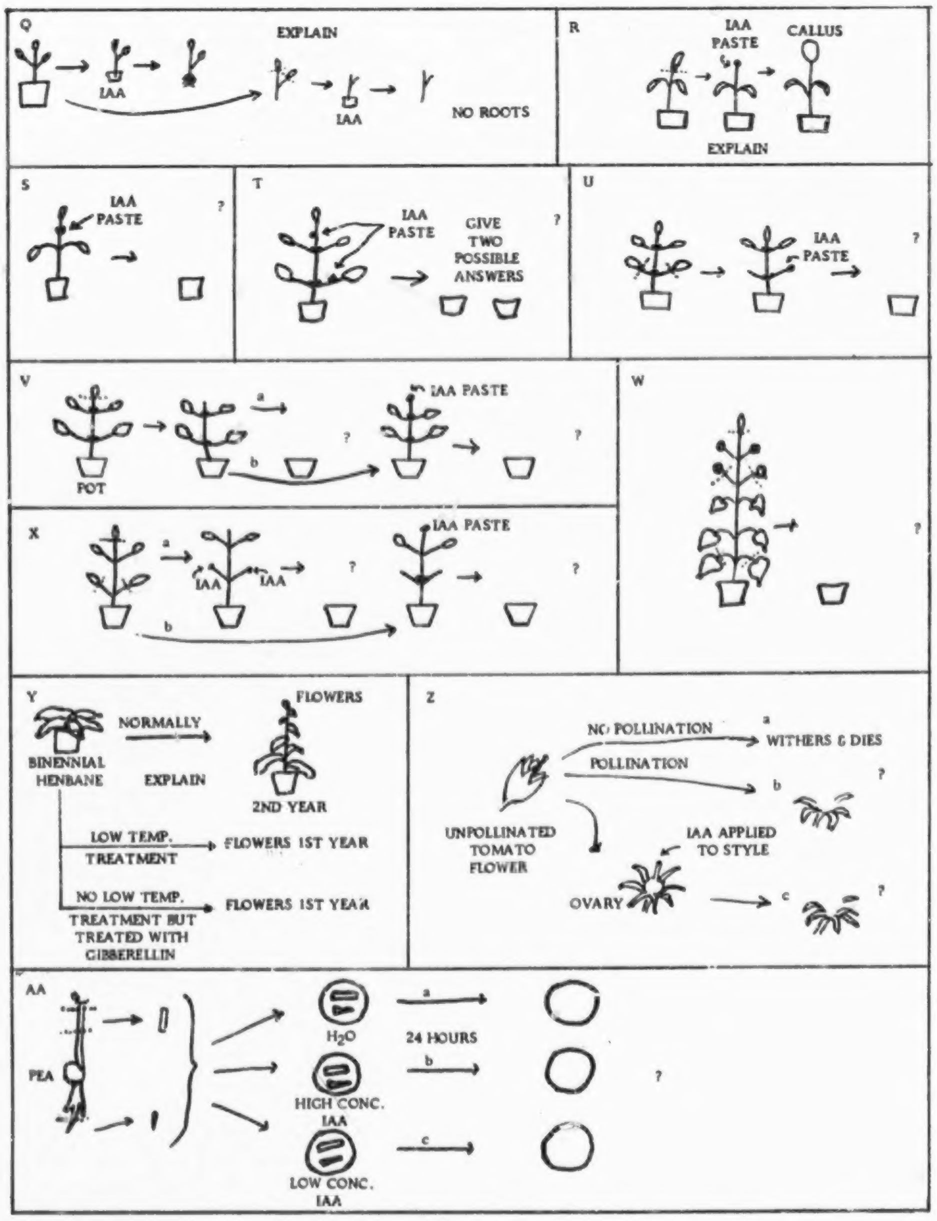
Based on this data, the experimenter hypothesized and tested his hypothesis, obtaining the following data:

Area Tested	Stem Girdle		Petiole Girdle
	Normal Plant μg. thiamin	Defoliated Plant μg. thiamin	μg. thiamin
Above Girdle	9.0	0.1	11.1
Below Girdle	0.07	0.06	1.0

What was his hypothesis, and did his data prove it? What is thiamin? Through what tissue does it move?

4. In the following _either_ complete the diagram, show what would happen with further growth, or explain the diagram.


A
?
LIGHT
OAT SEEDLING
B
AL FOIL CAP
EXPLAIN
BENDS
NO BENDING
C
EXPLAIN
BEND IN THE DARK
D
TIP REPLACED
EXPLAIN
BENDS
NO BENDING
BENDS
E
?
PLANT IS ROTATING
F
PLANT IS ROTATING
G
?
H
CORN GRAINS
I
TOP VIEW
LIGHT
J
GIBBERELLIN SPRAY
?
NORMAL PLANTS
DWARF CORN, PEAS, ETC.
K
H_2O
GIBBERELLIN
?
PEAS
L
?
SPRAY WITH CONC. 2,4-D
M
SAME AGE
?
UNSPRAYED ORANGE TREE
SPRAYED WITH DILUTE 2,4-D
N
SPRAY WITH ANTI-AUXIN
?
APPLE TREE
O
SPRAY WITH ANTI-AUXIN
P
EXPLAIN
H_2O
IAA
H_2O
IAA
H_2O
IAA


Q
IAA
EXPLAIN
IAA
NO ROOTS
R
IAA PASTE
CALLUS
EXPLAIN
S
IAA PASTE
?
T
IAA PASTE
GIVE TWO POSSIBLE ANSWERS
?
U
IAA PASTE
?
V
POT
a
b
?
IAA PASTE
?
W
?
X
a
IAA
IAA
?
b
IAA PASTE
?
Y
BINENNIAL HENBANE
NORMALLY
EXPLAIN
FLOWERS
2ND YEAR
LOW TEMP. TREATMENT
FLOWERS 1ST YEAR
NO LOW TEMP. TREATMENT BUT TREATED WITH GIBBERELLIN
FLOWERS 1ST YEAR
Z
NO POLLINATION
a
WITHERS & DIES
POLLINATION
b
?
UNPOLLINATED TOMATO FLOWER
IAA APPLIED TO STYLE
OVARY
c
?
AA
PEA
H2O
a
24 HOURS
HIGH CONC. IAA
b
?
LOW CONC. IAA
c

5. Three dwarf corn mutants (A,B, and C) were analyzed for auxin content and ability (+) or inability (o) to grow to normal size when treated with naturally occurring growth regulators. Give a logical explanation for the data in the table below.

Plant	auxin content Mg/100 coleoptiles	Growth response to added	
		IAA	Gibberellin
Normal	0.010	-	-
A	0.009	o	o
B	0.008	o	+
C	0.0001	+	o

HOMEWORK PROBLEM ANSWERS WEEK 1

1. Seedling grown in the dark: dry wt. less than that of the seed due to respiration; volume greater than that of the seed due to H_2O absorption.

   Seedling grown in the light: dry wt. greater than that of the seed due to photosynthesis; volume greater than that of the seed due to H_2O absorption. The normal sequence of events is H_2O absorption, digestion of stored food to sugar, respiration of sugar, energy for growth. Photosynthesis supplies the food when the stored food is gone.

2. 10^{-1}; 10^{-5}; 10^{-2}; 100,000 x; 10^{-9}; 10^{-6}; 10^{-8}.

3. Thiamin is a root growth hormone synthesized in the leaves and translocated via the phloem to the roots where it promotes growth. His data seemed to prove it.

4. A. The seedling will bend toward the light.
   B. The tip of the seedling receives the phototropic stimulus.
   C. The auxin from the cut tips move down the sides on which they are placed and cause the cells there to bend.
   D. The tip produces the auxin which causes the bending.
   E. The plant doesn't bend since the rotation causes the auxin to be equally distributed.
   F. Same as E.
   G. The plant bends upward since the geotropic response is stronger than the phototropic response.
   H. The coleoptiles grow up and the radicles grow down.
   I. The stem and petioles will bend toward the light, and the upper surfaces of the leaves will orient toward the light.
   J. Some of the dwarf mutants will respond and grow to normal height, others will not.

K. The plant sprayed with gibberellin will grow taller.
L. The broad leaf plants will die.
M. The sprayed tree will retain its fruit longer.
N. The spray will cause fruit fall.
O. The leaves will fall off sooner than normal.
P. The first pair of cuttings are evidently easy to root, the second pair harder to root, and the third pair very difficult to root.
Q. The leaves produce something required for rooting.
R. Auxin induces a tumor-like growth (callus) by stimulating cell division.
S. Auxin induces the formation of aerial adventitious roots.
T. Auxin causes the stem and petiole to bend away from the side of application, if the concentration is optimal for cell elongation. If the concentration is superoptimal, the bending will be toward the side of application due to inhibited cell elongation there.
U. The petiole on the left will soon fall off; the petiole on the right will remain on much longer.
V. In "a" the lateral buds will sprout; in "b" they will not.
W. The lateral buds will sprout and the two cut petioles and two cut fruit stalks will soon fall off.
X. In "a" the lateral buds will sprout; in "b" the two lower petioles will soon fall off.
Y. Henbane normally requires a cold winter before it will flower. Plants artificially treated with cold can be induced to flower the first year. Evidently gibberellin can substitute for the cold requirement.
Z. In "a" the flower will wither and die without producing a fruit; in "b" and "c" a mature fruit will be produced.
AA. In "a" little growth will occur; in "b" the stem's growth will be stimulated, the root's growth inhibited; in "c" the stem will grow little while the root's growth will be stimulated.

5. Mutants A and B contain a normal amount of auxin, whereas C contains only 1/100th of the normal amount. Evidently mutant C has lost the ability to synthesize its own auxin. This is supported by the fact that it grows to normal size when given IAA. Mutants A and B don't lack auxin so something else must be "wrong" with them. Mutant B responds to gibberellin so perhaps it lacks the ability to synthesize its own gibberellin. Mutant A responds to neither IAA nor gibberellin. The reason for its inability to grow to normal height is unknown and would require further study.

The text assignment for this week's study is from The Living Plant, Ray, pp. 97-106 and the Scientific American article, "What Makes Leaves Fall," Jacobs.

The Small Assembly Session

The student is scheduled to meet this session on the Monday or Tuesday following the study activities previously described. The student will initiate questions and participate in the discussion of questions asked by other students. He will have the instructor clarify any points which are not clear over the past week's study and make final preparation for a 20 point quiz. The last 20 minutes of the session will be devoted to answering questions on the following quiz.

BIOLOGY 108 WEEK 1 -- UNIT IX, P I 20 pts

NAME ____________________________

SAS Instructor ____________________ Div. ______ Seat No. ______

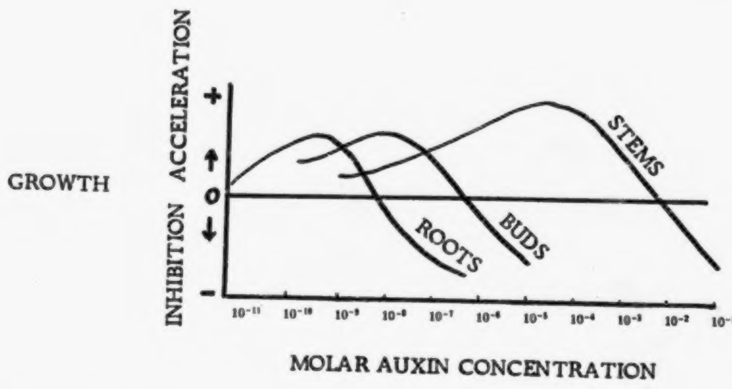
Compound X occurs naturally in Y plants and promotes the growth of Y leaves in culture. Using the hypothetical data in the table below fill in the blanks that follow.

Area Tested	Stem Girdle		Petiole Girdle µg. X
	Normal Plant µg. X	Defoliated Plant µg. X	
Above Girdle	1.2	0.4	0.9
Below Girdle	12.1	11.8	12.7

A HORMONE Compound X is probably a leaf growth __A__ which
B ROOTS is synthesized in the __B__ and translocated via
C PHLOEM the __C__ to the __D__ where it promotes
D LEAVES growth.

__B__ A young seedling grown in the dark will have a dry weight ((A) greater than, (B) less than, (C) equal to) that of the seed from which it was grown due mostly to
__B__ ((A) photosynthesis, (B) respiration, (C) water absorption, (D) digestion).

__A__ A young seedling grown in the light or dark will have a volume ((A) greater than, (B) less than, (C) equal to) that of the seed from which it was grown due mostly to
__C__ ((A) photosynthesis, (B) respiration, (C) water absorption, (D) digestion).



D Using the data in the above graph, pick out the incorrect statement. An auxin concentration of 10^{-8} would (A) have no effect on root growth, (B) stimulate bud and stem growth, (C) have a lesser stimulatory effect on buds if it were diluted 10X, (D) inhibit bud growth if it were 10X more concentrated.

E Refer to the handout sheet (The Laboratory Study Sheet - Week 1). There are six experiments and six conclusions. Which conclusion best fits diagram 5.

Pick out the one incorrect statement in each of the next 6 questions.

D (A) Leaves produce a substance(s) required for the rooting of cuttings. (B) A concentration of auxin which greatly stimulates root cell elongation would have little or no effect on stem cell elongation. (C) The roots formed on a cutting are adventitious roots. (D) Some cuttings will root in tap H_2O, others require IAA, while others require gibberellin and IAA. (E) A concentration of auxin that would cause a pea stem to bend would inhibit cell elongation in a pea root.

C (A) Spraying a citrus tree full of ripening fruit with anti-auxin will stimulate fruit abscission. (B) Spraying an apple tree full of ripening apples with dilute 2,4-D will prevent preharvest fruit drop. (C) 2,4-D and 2,4,5-T are selective herbicides in that relatively high concentrations kill narrow leaf plants while leaving broad leaf plants unharmed. (D) The epicotyl growth stimulant in problem 1 could have been gibberellin. (E) Gibberellin can substitute for the low temperature requirement in certain biennials.

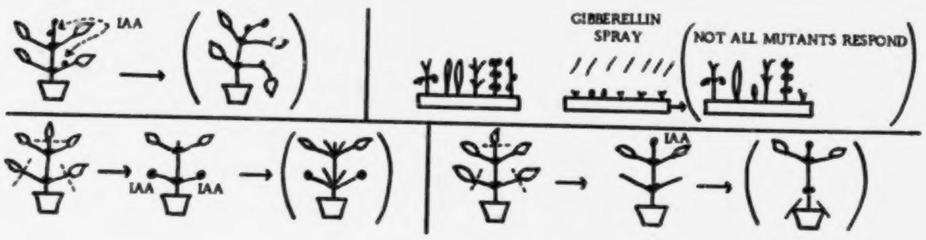
E (A) Most of a plant's growth occurs at night. (B) The tip of a growing stem describes an irregular path in space. (C) The folding of the leaves of the sensitive plant after they have been touched and the opening and closing of certain flowers in the morning or evening are nastic movements. (D) The twining of a stem around a pole is an example of a tropism. (E) A stem bends toward light because of the difference in the rate of cell division on the shaded side compared to the lighted side.

A (A) The sequence of information transfer when a gene is functioning is DNA → protein → RNA. (B) The sequence of information transfer in cell division is DNA → DNA. (C) Cell differentiation depends in part on the amount and plane of cell division and the amount and direction of cell elongation. (D) If it were not for the fact that different genes are functioning in different cells, differentiation would not occur. (E) Growth, an irreversible increase in size, involves cell division, cell enlargement, and cell differentiation.

D (A) A root which bends away from a certain chemical is exhibiting a negative chemotropism. (B) Auxin accumulates on the shaded side of a stem, and on the bottom side of a plant placed horizontally. (C) The auxin which accumulates on the lower side of a horizontally placed root, inhibits cell elongation there. (D) Most of the increase in length of a stem is due to cell division. (E) Heredity limits what an organism can do, and environment determines which of these things the organism will do.

F Auxin is directly involved in all but one of the following: (A) apical dominance, (B) rooting, (C) phototropism and geotropism, (D) leaf and fruit abscission, (E) fruit development, (F) starch synthesis, (G) callus tissue formation, (H) stem and root elongation.

Complete each of the following diagrams:



SCI. AMER. BONUS QUESTION

Describe the techniques used and some of the results obtained in the article, "What Makes Leaves Fall?"

Special Research Project

One of the three special research projects (Chap. 2) is an investigation of the effects of a growth regulator on certain plants. This study will not necessarily be performed coincident with this week's work but is mentioned here to call attention to the fact that the student has this additional opportunity to extend his knowledge of growth substances. The projects will be administered by the SAS instructor and will be completed either in the greenhouse or in the laboratory workroom. The following are the written directions received by the students as a mimeographed copy.

THE EFFECTS OF A GROWTH REGULATOR ON PLANTS

BIOLOGY 108

PROBLEM NO. 1

In problem no. 1 you will be given the materials and methods to use and what data to collect. It will be left up to you to analyze and interpret your data and make your conclusions.

Problem: Does growth regulator A (or B) promote or inhibit the growth of ____________, and how great is the effect?

Introduction:

The growth and development of a plant is influenced by many factors. These can be divided into two groups: environmental and biological. Environmental factors are external factors that can influence the plant's development, such as temperature, gravity, light, etc. Biological factors are internal factors, and are usually a result of the genetic constitution of the plant. Among these biological factors are many growth regulators. These chemical substances can influence the rate of cell division, the rate of cell growth, and the extent and type of cell differentiation.

Many growth regulators are synthesized by plants and can be extracted and purified. Others do not exist in nature but are synthesized by man. These substances, when extracted from one plant, can be applied to another plant and their effects studied. When the effects of a substance on a particular plant are well known, the concentration of said substance in an unknown solution can often be estimated by measuring its effect on the plant in comparison with identical untreated plants.

In the experiment that you are about to perform, you will test the effects of two different concentrations of an unknown growth regulator. From the measurements that you will make on your experimental plants, you will decide:

1. Whether the growth regulator that you used stimulates or inhibits the growth of your plants in comparison with the control plants.
2. Which of the two solutions that you used has the highest concentration.
3. How much (if any) the epicotyl, hypocotyl, and total height of the plants are affected by the growth regulator.

Materials and Methods:

In this experiment you will plant seeds of ________________ (__________) and test the resulting plants with two different concentrations of the same unknown growth regulator. People with their last names beginning with A through L will use unknown "A" while those beginning with M through Z will use unknown "B". Warning! One of these compounds could have a deleterious effect on humans so wash your hands after using the compounds.

1. Obtain 3 dixie cups, 3 wooden pot labels, and 15 ____________ seeds from lab (G-415). Take these to the BIO. 108 greenhouse. A map showing you how to get to the greenhouse is posted in lab on the bulletin board.

2. In the greenhouse punch at least 10 holes in the bottoms of the cups with the needle supplied. Fill the cups to within 1/4" of the top with the soil provided. Plant 5 ______________ seeds per cup at least 1/2" deep. Water the cups until the soil is quite damp. If any seeds become exposed, recover them with a little more soil.

3. Place a pot label in each cup with the following information written in pencil: the date you started, your full name, the unknown (A or B), and the individual treatment (concentration #1, concentration #2, or control). You may use both sides of the label. A sample label might read: 1/29/63, John H. Doe, B#2. Place your cups in your small group assembly area on the proper greenhouse bench.

4. Water these cups once every 2 days to start with and every day when the plants are well above the soil.

5. You will need 3 healthy plants per cup. Pinch off (don't pull up) any excess plants which come up. As soon as your plants appear above the soil you should begin your measurements. Take all measurements in the metric system. Measure the lengths of both the epicotyl and the hypocotyl of all the plants every

2 days. Also make observations on the general condition, color, and vigor of your treated plants as compared to your control plants.

6. The method and time of treatment of your plants is posted in the greenhouse. Be sure and use only the unknown assigned to you.

7. At the end of the experiment pull up your plants, select one representative plant from each cup, clean all the soil from their roots, place them between old newspapers, and place books or some other weights on them until they are dry. Glue or tape them to sheets of white paper and label them as to treatment. Label all the parts that are visible on your control plant. Place them in the RESULTS section of your report.

RESULTS:

List your data in both tabular and graphic form, using the average measurements for each cup. Place your pressed plants here.

DISCUSSION:

This is where you should analyze your results. Discuss the differences between the plants. Discuss whether you could detect a difference between the two concentrations. What part of the plants were most affected? A good portion of your grade comes from the discussion, and you will find it well worth your time to put a little thought into its writing.

SUMMARY:

In as few sentences as possible, tell what experiment was performed and what was concluded from the results.

LITERATURE CITED:

You should cite at least three references. Here are some references which are on reserve for you in the library in this building.

1. Audus, L. J. Plant Growth Substances, Leonard Hill Limited, London and Interscience Publishers, Inc., New York, 1959.

2. Hitchcock, A. E. Tobacco as a test plant for comparing the effectiveness of preparations containing growth substances. Contrib. Boyce Thompson Inst. 7:349-364. 1935.

3. Leopold, A. C. Auxins and Plant Growth, pp. 3-47. University of California Press, Berkeley and Los Angeles, 1955.

4. Bonner, J. and A. W. Galston. Principles of Plant Physiology. W. H. Freeman and Co., San Francisco, 1952.

SPECIAL NOTE:

This instruction handout was done in the same form which you should use for your reports.

Chapter V

OPERATIONAL ASPECTS

The operation of any course of necessity reflects the specific ideas and attitudes of the individuals who are presenting the course. The information in this chapter represents the opinion of the senior author as it has been modified by the experience of teaching a freshman botany course over a period of 14 years plus many ideas and procedures suggested by teaching assistants, students and other personnel associated with the course.

The following items are by no means a requirement to the success of the audio-tutorial system and should not be construed as a vital component of the approach. The course on which this information is based is a freshman botany course at Purdue University. The enrollment over the past 14 years has varied from 150 to as much as 480 students. It is a 4-hour credit course required for agriculture students, pharmacy students, forestry students, and may be taken as an elective by liberal art students. Conventionally, the course was taught by two 1-hour lectures per week, one 1-hour recitation, and one 3-hour laboratory per week.

Under the integrated experience system used at Purdue University, students enroll for 1 hour of general assembly per week, scheduled, 2 hours of small assembly, scheduled (only one of which is used), and 3 hours of laboratory, hours to be arranged. The students will be expected to attend only two scheduled sessions during the semester, that is, the 1 hour of general assembly and 1 hour of small assembly. The extra hour of small assembly for which they are registered and scheduled will not meet except on special occasions at the beginning of the semester. This will be a getting acquainted session and used to introduce the students to the procedure of the course. Therefore, the students have a four hours conventional equivalent which is arrange hours to be accommodated in the independent study session in the learning center.

Teaching Personnel

The course is in charge of the senior instructor, S. N. Postlethwait, Professor of Biology, who is the only instructor of professorial rank. Other personnel include Mr. H. T. Murray, a full-time instructor, eight half-time teaching assistants equivalents (these teaching assistants are working 1/4, 3/4 or full time), two undergraduate assistants and about half-time secretarial help.

The senior instructor has the over-all responsibility for the course. The general organization and planning of course content, procedures, timing of tests and items of this nature are decided upon by the senior instructor. His contact time includes being in charge of all of the general assembly sessions, meeting of all the students in the first small assembly session to introduce them to the course and to become acquainted (14-15 sections), 2 or 3 small assembly sessions on a scheduled basis, and 2 or 3 hours of contact time in the independent study session as monitor of the learning center. In addition, the senior instructor meets with all the students in small groups of 10 on an informal get-acquainted basis for 15-minute sessions at the beginning of the course and attends all briefing sessions for the personnel. The total contact time of the senior instructor is six or more hours per semester. The senior instructor prepares all of the audio tapes and prepares instructional materials used in the general assembly session.

The full-time instructor in the course, Mr. Murray, supervises the preparation of all other materials in the course. He is responsible for the writing of homework problems, test questions, setting up the practicals, planning and providing materials for miniature research problems, supervision of the preparation of independent study materials, and scheduling of work assignments. His student contact includes regularly scheduled small assembly sessions and monitoring the independent study session eight or more hours per semester, and occasionally he substitutes for the senior instructor in the general assembly session.

Most of the teaching assistants are working on either MS or PhD degrees. At the beginning of each semester each teaching assistant is assigned one or two units of study as his responsibility for preparation of materials for the independent study session. It is expected that he will listen to the tapes over the units assigned to him and become completely familiar with the materials necessary to be used for demonstration and experimentation for that particular unit. He supervises the growing of any live specimens necessary, makes sure that appropriate materials are available, places purchase orders for needed items, and develops other materials as needed. Under the direction of the full-time instructor, Mr. Murray, he plans the arrangement and distribution of materials on the demonstration table and within the booths. He can develop new innovations or variations of the original experiments where feasible and within the limitations imposed by the basic tape and budget. He is responsible for setting up the one booth as a guide for duplication by undergraduate help and is responsible for the maintenance of all materials on display during the time it is in use. He is further responsible for the disassembling and storing of these materials at the end of the presentation of his unit. His contact will include one or more small assembly sessions (after he has had 1 semester's experience as monitor in the independent study session) and several (8-10) hours as monitor in the independent study session. His total contact time will equal 10 hours per week. New teaching assistants are required to attend the general assembly session. It is anticipated that each teaching assistant will spend 10 hours per week in preparation which makes his work load about 20 hours per week. Naturally, during the week he is responsible for materials in the independent study session, his hours of work exceed the 10 hours per week preparation but a lighter work load for other weeks compensate for the extra time. His grading responsibilities involve the evaluation of students on oral exams, grading of one or two special questions weekly on the small assembly session quiz, grading his SAS section's research projects and entering final grades for his SAS students.

Undergraduate teaching assistants do much of the routine grading and menial tasks around the laboratory, such as washing of dishes, duplication of materials in booths, tearing down the booth and demonstrations, and work of this nature. On occasion they are brought in to assist the monitor in the independent study session at overflow times and when many students are taking quizzes.

The secretary, Mrs. Margery Booth, does nearly all of the clerical work involved in the course. She records all grades on a master card which is retained in her office. At mid-semester and at the end of the semester she makes a tabulation of the scores of all students and on the basis of a percentage point indicates a tentative grade. She makes up all mid-semester reports of unsatisfactory work for the signatures of the instructors who have charge of these students in SAS, and prepares the final grade cards for entry of the final grade. Although attendance is not required and absences are not penalized by the lowering of the grade, still it is desirable under this system to keep close check on the activities of the various students. Students who are doing poorly in the course and are excessively absent are reported to the Dean by the secretary.

The total number of teaching personnel and its composition is the same as that used previously under the conventional approach. The kinds of responsibility and the nature of the work load however are somewhat different in that each category of individuals associated with the course now has become somewhat more specialized and can be more creative in developing their area of contribution. It is possible under the integrated experience system to teach as effectively as with the conventional system using less personnel. However, the use of audio tape has in no way eliminated the desirability of having available teaching staff for personal contact with the student. Obviously the more instructors available to the student, the better the job can be done. There are many occasions where it is well to have two teaching assistants on duty in the independent study session, especially during the hours when much quizzing is involved. Undergraduate teaching assistants can be used on these occasions quite effectively, and it is feasible to have some of the better students taking the course to assist. In situations where only undergraduate personnel is available, the audio-tutorial system provides the advantage of having all students exposed to consistent information presented by the senior instructor. Thus, while the integrated experience system provides an opportunity for reduction of total personnel, it does not mean that this is a requirement. It enables the personnel who are operating to make more meaningful and direct contact with the pertinent problems of the students.

All people assisting in the course meet for one hour per week to discuss the activities of the past week and to prepare for the work of the coming week. The necessary work is not always accomplished in one hour of meeting, of course, and it is not expected that the total preparation of each individual for the following week is to be included here. It is anticipated that everyone will have listened to the tape on his own time and will have performed the exercises made available to the students. All instructors are expected to have read all the Scientific American articles and text assignments. The listening to the tape and performance of the exercises for the week's work gives consistent preparation for all the teaching assistants and should result in more consistent dissemination of information to the students.

The reaction of teaching assistants to the approach has been thoroughly positive. The significance of their role in the progress of the student has not been reduced but has been enhanced through the use of tapes. Their activities are now creative ones in the planning and development of their unit of work, and their teaching activities are now much more satisfying than under the conventional system.

Monitoring of an independent study session is a unique teaching experience. The teaching monitor is surrounded by a group of students all of whom are in attendance because they have chosen to be there at that particular time, and all know what they are to be doing and are setting about to complete their study as rapidly and as effectively as possible. Students are not trying to impress anyone, but are actively and in a determined way approaching their study. When a student requests assistance, he has a specific problem in mind and is in a receptive mood for the answer. As soon as he has become properly informed, he is ready to continue his work without further attention from the monitor. The monitor has an opportunity to deal with difficult concepts and to try a variety of approaches to its presentation. The monitor's technique of teaching is rewarded immediately and on a face to face basis with recognition and understanding by the student or else failure. In either event, the monitor learns immediately whether his technique is productive and can make alterations, if necessary. On many occasions, teaching assistants have come up with particularly effective programs or sequences of presentation of a given concept or idea and pass these along to the rest of the teaching personnel in the weekly session. All of this has contributed to the personal development and satisfaction of the teaching assistants. Teaching experience of the conventional type is available to those assistants who have had one semester of experience in the independent study session through their supervision of a small assembly session. Thus, contrary to the prediction of many colleagues, the morale of assistants has been unusually high and their contribution to the success of the program has been considerably greater than under the conventional system.

Text, Manuals and Readings

It is the opinion of the senior author that many students have a false feeling of security after having read the assigned chapters in a text. It is unfortunate that some students tend to equate reading a chapter with learning. Inasmuch as most conventional texts attempt total coverage of all of the subject matter of a given topic, often there are included many items and ideas which really are not useful to the progress of the student or are somewhat out of context. To avoid the time investment with these extraneous bits of information, paperback texts have been used in this course. The basic idea has been to provide the student an opportunity to read quickly the major themes of the topics without these concepts being lost in the minutia which so commonly is associated with their presentation in a conventional text. The paperback texts used currently in this course include the Plant Kingdom by H. C. Bold and The Living Plant by P. M. Ray. Naturally it is a matter of the instructor's judgment as to which text best fits his ideas. The workbook used in this course is one which has been especially prepared for use with the audio-tutorial program and is entitled Plant Science - An Audio Programmed Approach by S. N. Postlethwait. It includes pictures and diagrams, many of which have items labeled with an identifying number or letter used to direct the attention of the student to these items during a tape discussion. As the information warrants, pathway charts and diagrams have been included for use as an outline for the student as he listens to the tape. Laboratory exercises of the conventional type have been included and many of the exercises have been designed in such a way as to have the student introduced to the exercise by a short lecture or discussion from the tape followed by the performance of the exercise by the student and this followed by a confirmation or rejection of the student's conclusions as he listens to a further discussion on the tape. In many cases, much of the note taking and drawing has been eliminated through inclusion of drawings and photographs in the manual, and emphasis is placed on the student learning through listening, reading, and involvement in manipulation of materials. The text, manual and tapes provide the basic information which it is hoped the student will assimilate. Additional depth and perspective are provided the student through his reading of Scientific American articles, reference texts, viewing of specialized films, and special displays in the learning center. Again, it should be emphasized that while this procedure is used by the authors in the introductory botany course at Purdue University, many variations from this plan could be useful and perhaps more effective, depending upon the objectives of the instructors involved.

Grading System

The grading system employed is based on the idea that, if the teacher can accurately define the objectives of the course, and if all students attain a reasonable level, all students should be rewarded with a satisfactory grade. It is recognized that the senior author is not joined in this opinion by many educators. Inasmuch as this is true and the grading system is not a vital component of the integrated experiences system, the following information is presented only as a matter of information and not as a requirement for the system.

Grades are calculated on the basis of the number of points accumulated by the students in relation to an arbitrary number of points which he might earn. 90% = A; 80% = B; 70% = C; and 60% = D. All students receiving points less than 60% of the total points possible receive an F. Students accumulate points through a series of quizzes and exams. Weekly quizzes are given to keep the student informed of his progress and to guide him in his study habits. A brief experiment in which the students were allowed to delay quizzing for three weeks resulted in a considerable pile-up of students wanting to use facilities at the last moment. The weekly quizzes are of two kinds; one is a 10-point oral which is given in the learning center at a time selected by the student and the other is a 20-point quiz given in SAS. When the student feels he has mastered the subject matter satisfactorily, he will ask the instructor on duty to give him his 10-point oral quiz. This oral quiz is an evaluation of the student's progress rather than a series of specific questions. It is expected that the teaching assistant will confront the student with the materials at hand which have been used during the week's study and that the student will then explain, demonstrate, or identify various items through a brief discourse. The extent and nature of the discourse will depend on the teaching assistant and student involved and should take about 5 minutes. When the teaching assistant is satisfied that he can categorize the student on the basis of 0 to 10 points, he indicates the student's score and name on a slip of paper and this is filed for later entry on the permanent record card in the secretary's office.

It is logical that many students even on a weekly quiz basis, will begin their study early in the week, continue throughout the week and still not be ready for the oral quiz until the end of the week. Where as many as 500 students are involved, this may result in a large number of students wanting to take their exam during the last few hours of the last day of the week. To avoid this situation, testing on the last two days of the week is done on a scheduled basis only. Each week a list of time intervals at which one or two students per 15 minutes can be accommodated is posted. Students who wish to delay testing until the last two days of the week, sign their names opposite the time at which they wish to take the exam. The availability of these times is on a "first come, first serve basis". The reliability of the oral quiz is in question, and perhaps there is a better system for accomplishing the weekly practical quizzing. It has been the experience of the authors that the oral quizzes have had several useful effects, especially important has been the nature of the preparation of the students for this quiz. One result has been that students give each other pre-quizzes as they circulate about the laboratory -- a very excellent learning situation. Further, it eliminated the common practice of students trying to search out which specific questions are being asked this particular week. Their preparation is devoted to learning all they can about the material so they can impress the instructor with how much they know about the subject. Inherent in this system, of course, are the errors in judgement of the instructors and variation in their requirement for the different levels of attainment. Despite this disadvantage, the student will ultimately have been exposed to a large number of points and may exercise some initiative in selecting the instructor who will give him his quiz. The advantage gained through the nature of study and motivation by the oral quiz seems to outweigh the abuses which may arise.

A 20-point quiz of the conventional type is given each week in the small assembly session. Information included on this quiz is from the general assembly session, the homework problems, the independent study session and the text. A bonus question over information from Scientific American articles is usually included for a maximum of three points at the end of the regular quiz. This is done to motivate students to do extra reading but, since many of the Scientific American articles include relatively difficult material and the basic information of the course has been included in the independent study session, general assembly session and the text, it is felt that the bonus nature of these questions is justified. Most of the questions included on the 20-point quiz are of such nature as can be graded by machine or an undergraduate assistant. However, one or two questions are usually included which require grading by the instructor in charge of the small assembly session.

At the end of the semester, a 100-point comprehensive exam is given which uses the 20-point quizzes as the source of questions. Also, a 100-point practical exam is given at this time. It involves the placing of various items such as microscopes, experimental equipment, etc. in stations around a laboratory and the student is asked to answer questions about the items as he proceeds from station to station. Students sign up in groups of 50 at a time which is convenient for them.

The three research projects required also contribute to the grade. Inasmuch as the research projects are of such nature as to teach the scientific method and to cause the student to participate in research, all students are expected to do some of these projects. As with all term papers and projects of this nature grading is difficult; since many instructors are assigning grades, several inequities may result. To avoid these variations and provide some flexibility for individual differences yet to keep the research projects as a meaningful component of the course, the research projects are graded only on the basis of satisfactory or unsatisfactory. The first project, in which complete directions for completion are given is required of all students for a passing score in the course. The second project, in which more is left to the creativity of the student, is required of the B and A students. All three projects are required of A students. Failure to complete the second and third projects will place the student at a C level or less regardless of the percentage of points attained on quizzes and tests.

Again, it is emphasized that this grading system is not a basic part of the integrated experience concept but represents only the opinion of the senior author. The system will be effective with any kind of grading system which is reasonable, but requires frequent or regular quizzing on a weekly or biweekly basis. Frequent evaluation, however, is supported in the literature as sound pedagogical practice.

Records

To satisfy the requirements of the registrar's office and to keep from losing the identity of individual students, it is necessary to have an effective system of records. While grades are not based on the amount of time spent in ISS, SAS or GAS, it still seems desirable to have a reasonably accurate record of the activities of all students. To facilitate this in the independent study session a check-in check-out card has been designed as mentioned earlier which is manipulated entirely by the student himself and doubles as an efficient means of assigning booths. Affixed to each card is a picture of the student and blanks are on the card for entry of times at which he checks in and checks out. Some of the statistics included in Chapter VI were obtained in this way. A teaching assistant keeps a record of the attendance in the general assembly session, and a record of quiz grades indicates student attendance in the small assembly session. As mentioned earlier, the Dean's Office is informed of students who are doing poorly in the course and have excessive absences.

Photographs are taken of each student at the first small assembly session. Each photograph is identified by having the student hold a large card bearing his name. Three photographs are produced from the 35 mm negative by contact prints. One photograph is placed on the check-in check-out card, one on a permanent grade record card in the secretary's office and one is used to make up a large chart showing the seating arrangement in the general assembly session. All grades are turned over to the secretary on a weekly basis for recording on the permanent record card kept in the secretary's office. The card contains information as shown on the next page.

In addition to these records, each instructor of a small assembly session is expected to keep appropriate records and information concerning the progress of each student.

How to Prepare an Integrated Experience Lesson

One of the advantages of the I E system is that it forces the instructor to evaluate his procedures and to reconsider his objectives. It is a common fault of many of us to spend little time in the careful planning of the presentation of a course. We do many things with limited preparation and depend on our earlier experience of teaching the subject to cause us to do and say the right things at the right time. Most of us are resistent to change and sometimes we cling to ideas which have outlived their usefulness, thereby handicapping the kind of progress we should be making.

NAME ______________________________ ____________________
Last First Middle School-Semester

Wk.	RECIT. QUIZ (20)	LAB QUIZ (10)	LAB PRACT. (100)	CUM.	PASS.	CUM. POSS.
Wk. 1-Unit I	___	___		___	18	30
2 II	___	___		___	36	60
3 III	___	___		___	54	90
4 IV, P I	___	___	___	___	102	170
5 IV, P II-IV	___	___		___	120	200

GRADE

Wk.	RECIT. QUIZ (20)	LAB QUIZ (10)	LAB PRACT. (100)	CUM.	PASS.	CUM. POSS.
Wk. 6 V, VI	___	___		___	138	230
7 VII	___	___		___	156	260
8 VII	___	___	___	___	204	340
9 VIII	___	___		___	222	370
10 IX, P I	___	___		___	240	400
11 IX, P II-IV	___	___		___	258	430
12 X, P I-III	___	___	___	___	306	510
13 X, P IV	___	___		___	324	540
14 XI	___	___		___	342	570
15 XI	___	___	___	___	372	620

PROB. 1 ______ 2 ______ 3 ______ ______
FINAL ______(100) ______ 432 720
GRAND TOTAL ______ GRADE ______

NAME ____
Last First Middle

LOCAL ADDRESS ________________________________

HOME ADDRESS ________________________________
Street

____
City State

LOCAL PHONE ______________

STUDENT NO. ______________

OPTION ______________________________

FUTURE OCCUPATION ______________________

SMALL ASSEMBLY SESSION ______________________

DATE ______________________________

	M	T	W	T	F
7:30					
8:30					
9:30					
10:30					
11:30					
12:30					
1:30					
2:30					
3:30					
4:30					
5:30					
6:30					
7:30					
8:30					
9:30					

COMMENTS:
Total absences
Lecture ______
SAS ______
Laboratory ______

The following steps are suggested as a procedure for the development of an I E lesson.

Step 1. List all of the objectives of the unit. By this it is meant that the teacher should list as carefully as possible each achievement which he expects the student to accomplish keeping in mind the level or degree to which the students should attain. The list should include skills, concepts, vocabulary building, problem solving, creative activities, etc.

Step 2. List all of the available media and teaching aids which might be useful in accomplishing the above objectives. These include: paragraphs to be read from the text and periodicals, exercises to be completed from a manual, specimens to be observed or examined, experiments to be completed, homework problems to be worked, films to be viewed, and the many other items that might be useful in this regard.

Step 3. Select the media adapted to the subject. List alongside the items to be accomplished, the method through which they can best be done. Some items might be included in the general assembly session, some in a small assembly session, some on the tape (programmed by tape), some on film, and some in the home study session.

Step 4. List the study activities in their proper sequence. Consider carefully those items which can be used as a foundation for subsequent ones and align each item in a properly programmed sequence.

Step 5. Assemble the materials to be programmed by the audio tape. With these materials and a tape recorder, a trial tape should be made. Perhaps it would be useful to have a student helper do each item and the instructor record his voice as he directs the activities of the student through the entire audio taped program. If the student helper is an average student, his questions should be very useful in determining what points need to be elaborated and what items can be reduced or eliminated. Further, this approach should give the tape a tutorial flavor which would cause each student to feel the instructor was talking directly to him.

Step 6. Have the audio tape transcribed and edited critically. This step should enable the instructor to make sure the words he uses express precisely the information he wishes to present and to eliminate much of the redundancy which occurs in ordinary conversation.

Step 7. Make the final tape. It is probably better for most of us to make a final tape from a manuscript which has been edited and been typed in capital letters. Emphasis markings and other helps can be entered at the discretion of the instructor. Hopefully the tape would be produced in a conversational tone as if the instructor were speaking to only one student. In some cases it may help to have a student as an audience during the final taping of the lesson. Ad-libbing and background noises may result in lower quality tape; however, if they are not too distracting, they might contribute to the naturalness of the presentation. The authors have done no experimentation in this regard, but feel that the most straightforward presentation is probably the most effective and efficient. Interruptions to break up the monotony of listening to the tape will most likely come in the form of the performance of experiments, observations, demonstrations, reading of the text or laboratory manual, and other study activities. It has been the practice of the authors to retain the master tape on file to be used only in the production of additional tapes. The Audio-Visual Department at Purdue University is equipped to produce three tapes from one master at a very rapid rate through the use of relatively inexpensive student labor. Where this facility is not available, it should be possible to play the master tape on a conventional tape recorder and re-record on one or more conventional tape recorders simultaneously.

Costs

It is impossible to calculate accurately the cost for a comparison of the integrated experience system and the conventional system unless one is able to define specifically all of the associated materials and the situation under which the system has developed. A switch from the conventional system to the integrated experience system involving the use of existing materials compounds the difficulty of cost estimation. Despite this lack of accuracy, certain definite savings are obviously accrued as evidenced by the very nature of the number and kinds of items involved. For example, since only one or two students are at a given point in their study at any single time, one or two items of equipment can be used by a large number of students, in contrast to the conventional system where it is necessary to supply enough of that particular item for one or more laboratory groups proceeding simultaneously. Thus, expensive materials such as delicate instruments or slides cost less because a few will be adequate for a large number of students. The savings on staff time comes when the system is used in large courses. Perhaps the most efficient number is above 300 students. Higher quality of instruction can be given with the integrated experience system and a low number of staff, but, as with the conventional system, the more staff available the more quickly and directly one can care for specific needs of the students. In other words, the use of the system does not replace the need for teaching assistants but only provides the possibility of doing a better job of teaching when the total staff available is limited. Also, since much of the information is in the voice of the senior instructor and has been developed by him, it now becomes feasible to use undergraduate teaching assistants who are not able to handle a complete section but are able to handle questions on an individual basis.

Space savings result from more efficient usage of laboratories. Times when students cannot be routinely scheduled to attend classes are usually convenient for some students and these times are used on a volunteer basis. Perhaps most important is the time saved by not having space occupied by students who are not actually participating in the class. This includes students who already know the subject matter and those who do not care to learn it. Students in both categories are often captive audiences under the conventional system and occupy space unproductively. The following tables include some cost estimates and indicate some items on which savings may result. Actual savings would have to be calculated on an individual course basis.

Publisher's Note - 1966

Because data listed in tables 5.1, 5.2, 5.3, 5.4, and 5.5 is based on author's experience and 1962 costs, we invite your writing us for current information.

COMPARISON OF ESTIMATED COSTS, SAVINGS OF STAFF, AND FACILITIES

TABLE 5.1

	Conventional (1)	Audio-Tutorial (2)
STUDENTS	480	480
COURSE ORGANIZATION		
Sr. Staff	1 3/4	1
Instructor	1	1
Teaching assts.	10 (1/2 time)	8 (1/2 time)
Course Credit	4 hrs.	4 hrs.
Class meetings	Lect. 2 hr/wk Recit. 1 hr/wk Lab. 3 hr/wk 1 Semester	Gen. Assembly 1 hr/wk Small Assembly 1 hr/wk Unscheduled study session 4 hrs/wk 1 Semester

Factors to Consider

1. Slow students can proceed at their own pace and are not limited to the conventional 3-hour module for lab.
2. Scheduling is done by the student and time-blocks for large numbers of students are not a problem to advisors.
3. Staff requirements show a decrease and will show only a minimal increase for expansion.

TABLE 5.2

	(1)	(2)
SPACE		
Prep Room	1	1
Greenhouse	1 section	1 section
Auditorium (420 capacity)	4 hrs/wk	2 hrs/wk
Recitation Room	16 hrs/wk	16 hrs/wk
Laboratory (36' x 26')	1 room full time and an additional room for 9 hr/wk (14-3 hr. sessions)	1 room full time 22 booths 7:30 AM - 10:30 PM daily except Sat. and Sun.
Expansion potential for lab. room	798 students (2 rooms full time)	800 students (1 room full time)

Factors to Consider

1. Space requirement would increase for small assembly at the rate of 1 room /1 hr/week/30 students; for general assembly, no increase up to 840 students; and, for audio tape session, 1 booth/20 students.
2. Time not normally considered suitable (lunch-time, dinner-time, and evenings) can be used by students who have unusual schedules.
3. One lab room can accommodate up to 600 students while it takes two lab rooms for the conventional approach.
4. Reduced scheduling for large lecture hall releases the hall for other uses.

COMPARISON OF ESTIMATED COSTS, SAVINGS OF STAFF, AND FACILITIES

TABLE 5.3

	(1)	(2)
EQUIPMENT		
Microscopes	72	22 (1/booth)
Slides & similar equipment	72	22
Plant materials, etc.	72	22
*Certain demonstrations & set-ups for experiments	18	1 or 2
Tape players	0	22
Tapes	0	22 sets

Factors to Consider

Less equipment and fewer demonstrations will serve more students.

TABLE 5.4

	(1)	(2)
COST ESTIMATE		
Equipment		
Tape players	0	22@ $100 = $2200
**Tapes	0	22 sets@ $140 = $3080
***Booths	0	22@ $ 10 = $ 220
Microscopes	72@ $125 = $8800	22@ $125 = $2750
Hot plates	18@ $ 20 = $ 360	2@ $ 20 = $ 40
****Other	18@ $100 = $1800	2@ $100 = $ 200
Total	$11,960	$8,490
Supplies Estimate	$1,500	$1,000
Staff		
Sr. staff @$10,000	1 3/4 $17,500	1 $10,000
Instructor	1 $ 6,000	1 $ 6,000
Teaching assts. @$2,200	10 $22,000	8 $17,600
Total	$45,500	$33,600
Grand Total	$58,960	$43,090

Factors to Consider

1. If one were initiating a new course, the total estimated cost would be $15,870 less the first year.
2. A conversion to audio-tutorial from conventional teaching involves an estimated equipment savings of $8,970 which is ample to cover the $5,500 investment in tapes, players and booths.
3. Estimated salaries amounting to $11,900 annually are saved in the use of audio-tutorial. This figure becomes more significant if it is recalled that the ratio of increase in staff time to increase in students is about two additional hours of staff time per week per 25 students.

Footnotes

*A class of 36 students proceeding at the same rate and performing experiments or viewing demonstrations simultaneously may require at least 9 duplicate set-ups (2 simultaneous sections -- 18 set-ups). Since students using audio tape are proceeding independently, there are seldom more than one or two students requiring the use of a set-up at any given time. For example: two transpirometers were adequate to provide data on air bubble movement as a reflection of transpiration rate for 480 students.

**Cost of tape and tape players are a non-recurrent expenditure. Repairs and replacement costs are yet to be determined. Costs used are arbitrary since retail figures are not available.

***Booths were made by placing pegboard dividers on existing tables.

****Some equipment and supplies are materially reduced because of their more efficient use. The figure included is a rough estimate.

COMPARISON OF ESTIMATED COSTS,
SAVINGS OF STAFF, AND FACILITIES

TABLE 5.5

	(1)	(2)
TIME (Per Week)		
Staff		
Sr. staff contact hrs.	18	12
Teaching assts. contact hrs.	104	88
Preparation hrs.	110	90
Total	232	190
Student	2,840	2,160

Factors to Consider

1. With an increase of 30 students, staff contact time in the small assembly would increase 1 hr/wk. Other associated staff activities would increase at about 10 hrs/wk/200 students.
2. Facilities are not occupied by students who have already mastered the subject matter or by students unwilling to study. (This improves student attitude and minimizes idle activities which are destructive to equipment and morale.)

Achievement and Problems of the Integrated Experience Approach

The integrated experience system must not be confused with the use of audio tape as a substitute for the lecturer or teacher in the classroom. It is a programming of a sequence of study activities in the voice of the senior instructor. In contrast to other media, such as television, the student has control of the rate at which he proceeds with his study, an opportunity to replay as often as he desires, but most important of all, all of the conventional experiences involving the actual handling of specimens, doing experiments, manipulating the microscope, and other items of this nature are retained. There is no attempt to substitute the sound of an instructor's voice for the performing of an experiment, collecting data, and making an analysis of these data. Many of the modern gadgets for teaching have attempted to use one medium of communication as the only source of all of the student's learning. Most subject matter, by nature, requires a variety of approaches, therefore, attempts to reduce student involvement to one or two sensory organs have met with unsuccessful results. These experiments have prejudiced many teachers against adopting or experimenting with the use of modern communication media. While these experiments have been unfortunate, we must not let them blind us to the true advantages of the teaching aids which can give us real assistance in helping our students learn.

In the audio-tutorial approach:

1. Emphasis is placed on student learning rather than on teaching.
2. Students can adapt the study pace to their ability to assimilate the information. Exposure to difficult subjects are repeated as often as necessary for any particular student.
3. Better students are not a "captive audience" and can use their time most effectively. Their interests are not dulled by unnecessary repetition of information already learned but they are free to choose those activities which are more challenging and instructive.
4. The student can select a listening time adapted to his diurnal efficiency peak.
5. Tapes demand the attention of the students. Students are not distracted by each other.
6. Students have more individual attention, if they desire it.
7. Scheduling problems are simplified. The four hours of scheduled time from which the students are relieved under the new system can now be distributed throughout the week as necessary to adjust to the student's activities.
8. More students can be accommodated in less laboratory space and with less staff.
9. Make-up labs and review sessions can be accommodated with a minimum of effort.
10. The student feels more keenly his responsibility for his own learning.
11. Each student is essentially "tutored" by a senior staff member.
12. Potentially, the system can be used to standardize instruction where desirable, e.g. between the University and the University Centers.
13. Opportunities for research on learning processes is enhanced.

STUDENT ACHIEVEMENT

No valid testing program has been set up to evaluate the achievement of the students under the I E system, as compared with the conventional system; however, the senior author has taught the same course for the past 14 years, and the following evaluation represents his judgment as to a comparison of the two systems. More students can reach a higher level of achievement under the I E system. Students' attitudes are considerably improved, vandalism is reduced, and at least one third more information can be presented in an equivalent length of time. The students are able to do more sophisticated experiments and, according to feedback, limited though it is, the retention span is considerably extended. The grade distribution for the four semesters for which the experiment has been under way and for over 1200 students is as follows:

GRADE DISTRIBUTION FOR STUDENTS UNDER THE INTEGRATED EXPERIENCES SYSTEM

TABLE 5.6

First Semester		Second Semester		Third Semester		Fourth Semester	
A	19%	A	19.5%	A	13%	A	24.5%
B	24%	B	24.5%	B	21%	B	40.0%
C	30%	C	30.0%	C	34%	C	22.5%
D	14%	D	13.5%	D	21%	D	6.5%
F	13%	F	12.5%	F	11%	F	6.5%

This is in contrast with 7% A's, 16% B's, 38% C's, 20% D's and 18% F's under the conventional system. The percentage of F's decreased somewhat, but apparently the high percentage of failures is to be expected in a freshman course where many students have not yet adjusted to college. (Recall the grading system (see p. 87) is based on an absolute standard - not on a "curve"). Perhaps an improvement in orientation of these students at the beginning of the semester would reduce the number of failures still further. It should be emphasized here that more students attained a high level of achievement and that this was accomplished under higher standards. A record of time spent in the independent study session reveals that there is a direct correlation to the grade level attained and the amount of effort put into the course up to a certain point (see Chapter VI). Similar results have been obtained by W. Westerfeld at Penn State University using materials prepared independently.

INSTRUCTIONAL ADVANTAGES.--There are certain advantages of the system for the teaching personnel as well as for the students. The critical programming of all of the learning activities in a unit of information to be presented causes the instructor to organize his presentation in an effective and efficient fashion. A carefully planned program, once organized and put into practice, enables the senior instructor to spend his time in more meaningful contact with the students. This contact is a more pleasant situation than under the conventional situation where the meeting between the senior instructor and students is marred by routine and detailed presentation. The instructor now meets the students on a more friendly and informal basis.

The training of new teaching assistants in subject matter is easier and less involved. The new teaching assistants are required to go through the program in the same manner as a student in the course. This they can do without special effort on the part of the senior instructor and at their own convenience instead of having to find an occasion each week in which all teaching assistants can be brought together for special instruction. The teaching assistants are better prepared because they receive immediate feedback on the effectiveness of their presentations in their face-to-face contact with students in the independent study session, and can determine quickly whether or not they are really familiar with the subject matter or whether their teaching procedure is a helpful one. They also gain experience in the more formal presentation in the SAS. After one semester's experience in the ISS, they are placed in charge of a SAS section of their own and have an opportunity for the more conventional type of presentation. Their responsibility for the production of materials for a unit of work in ISS has proven to be an inspiration to do excellent work. They have an opportunity to be creative in developing the program for the unit, and they are exposed to the full range of experience in developing a unit of work. The morale of the teaching assistants has been very high and their contribution to the success of the program has been a significant one.

CONTINUING PROBLEMS.--One of the greatest problems in the development of the I E system is the tremendous amount of effort that is required by the senior instructor and his assistant in developing the initial tapes and outline of materials. The time investment for the senior instructor outside the classroom and during the early stages of program development is at least double that of the conventional system. Any senior staff setting up such a program should not anticipate any other responsibility during the semester in which the program is developed.

A pile-up of the students at favored times of the day for the independent study session constitutes a problem during the first two weeks of operation. The pile-up results from two situations: one is the favorite time of day and the other is the natural consequence of study habits. The authors have solved the first problem by publishing on the bulletin board a record of the number of students present in the independent study session at every hour the learning center is open. The students can check the slack times and arrange their schedules accordingly. The pile-up for quizzing has been taken care of by having the students sign up for a quiz at a specific time, or taking quizzes as early as they desire.

Professor Walter Westerfeld at Pennsylvania State University, using the audio-tutorial program and oral quizzes in the same manner, has used a sign up system for reserving a booth in the learning center. His procedure allows the student to sign up for a booth for any time and number of hours he might desire. However, if the student is not present to occupy the booth at the time for which he has signed up, any student who may be present may use that booth. He reports that this has been a very successful approach to taking care of the pile-up times. There are probably other solutions to the problem, one of which might be to schedule a portion of their time and leave a portion unscheduled. Each student would be assured of a measure of time in the booth. However, some of the merits of the program are lost when one returns to rigid scheduling. The opportunity for the student to delay his study of one subject until it is convenient or fits into his program for the week is one of the important features of the I E system. On occasions the student may find it desirable to complete his study for the week in the early part of the week. On the other hand, if a difficult test is coming up in some other subject, it may be desirable for him to delay his study in the audio-tutorial presented course until after his test has been completed in the other subject. While piling up does constitute a problem, it is not an unsolvable one and seems to give more concern to the administrators and instructors in the course than to the students themselves. The emphasis given to this problem is largely a consequence of the relatively few problems encountered with the I E system, thus the problem appears out of proportion to its significance.

One of the major problems in the I E system, is to communicate to the students the difference between this approach and the conventional procedure. Students have been accustomed to reading a chapter or attending a scheduled class session and feel that in doing so they have somehow absorbed information and will receive credit for their effort. Under the I E system with no specific time requirement, some students find it difficult to adjust their approach to study and spend their time ineffectively with the tape. There is a tendency on the part of some to listen to the tape as though it were another lecture. They listen to the tape without interruption, then try to complete the exercises. This approach to study nullifies the basis on which the whole program is established, and the student is now operating as under a conventional approach. Only when each exercise is done in context and as programmed is the system fully effective. Fortunately, many students come to realize this after three or four weeks of experience, and in many cases there is a dramatic change in their level of grade performance. A strong effort is made to help students understand the nature of the learning process, and the reaction of students has been positive in this regard. Many students have informed the senior instructor that they have now learned how to study and use the same procedure in other courses.

Chapter VI
POTENTIALS FOR THE INTEGRATED EXPERIENCE APPROACH

Accommodation for Individual Differences

As pointed out earlier, students vary widely in the time they require to master a given body of knowledge. The rate of learning of new material is partly a function of past experience in the discipline, but there is some evidence that students, with a varying aptitude spectrum, approach learning tasks differently. The flexibility available in the I E system has a high potential for accommodating for both differences in background knowledge and differences in student's approach to learning.

It is possible to devise examinations that require students to interpret tabular or graphic data, draw inferences from observations and in other ways test the student's ability to think analytically. In a preliminary study of differences in information acquisition rates for botany students, it was found that time spent in the audio-tutorial booth was related to total scores on tests of botanical knowledge. However, the relationship was much more striking when the group under study was divided according to analytic ability, i.e., students scoring in the upper, lower, and middle thirds on a test of analytic ability were treated as distinct groups. In Figure 6.1 it will be noted that hours of study in the audio-tutorial booth, a principal learning experience for most students, shows a positive correlation with score on a 100 item test of botanical factual knowledge. However, when grouped by analytic ability, it can be seen that knowledge gained by the middle analytic group was greater for a given amount of study time and knowledge scores for the high analytic group were higher than for the lower two groups, with mean scores for high analytic group working in the booth only 9 hours in a five-week period exceeding the mean scores for students in the middle analytic group working for 20 hours in this same period.

These data should be interpreted cautiously, since further analysis of learning in an Audio-tutorial system is needed. Herein lies one of the very important potentials of this system; it is possible to program instructional material in varying ways and observe the effectiveness of those varying training regimes on student achievement. Over the years we may discover that

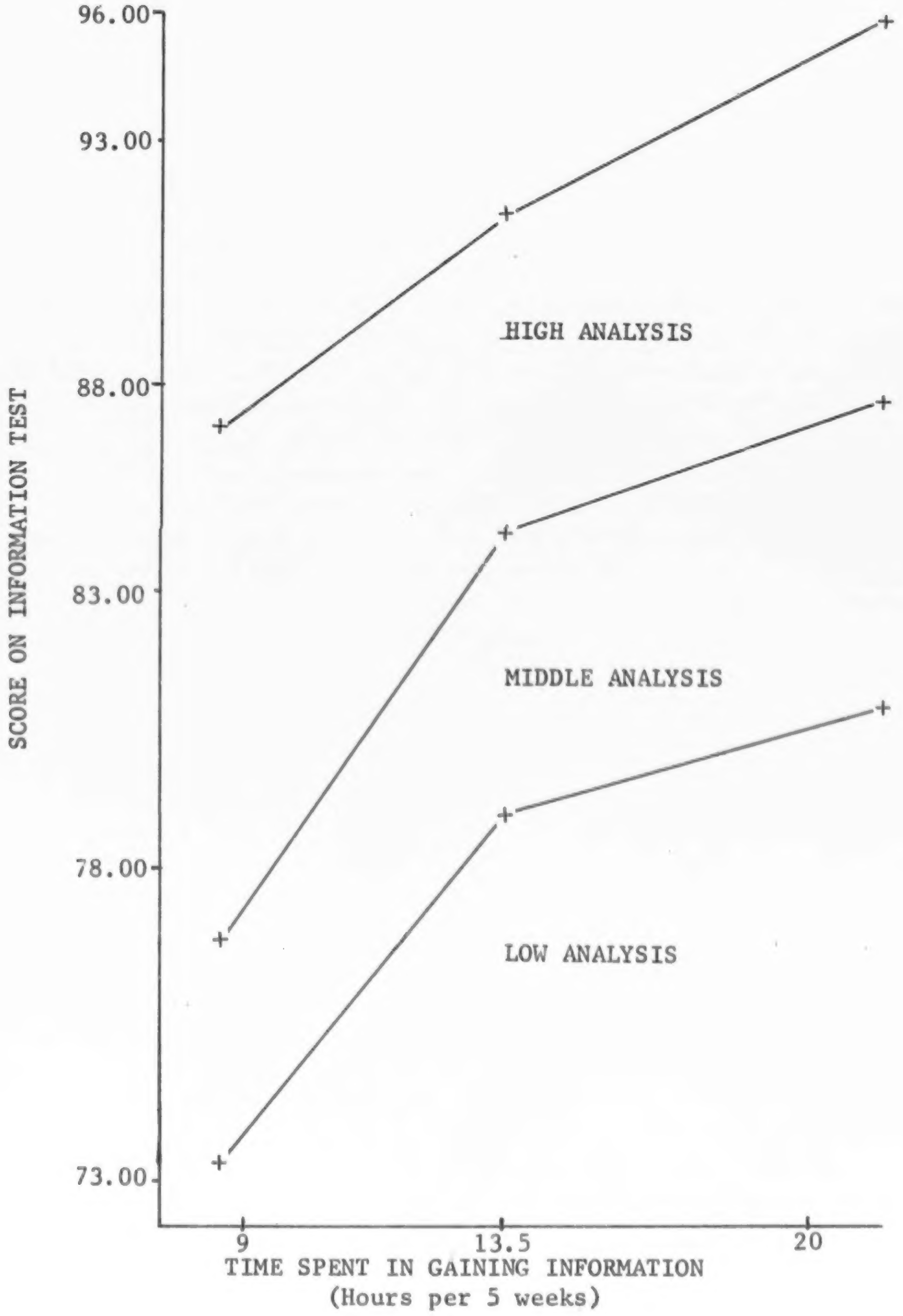


Figure 6.1 - The effect of analytic ability and time spent in gaining information on information store.

certain training regimes are much more effective for one type of student and other training regimes are equally effective for another type of student. The flexibility of Audio-tutorial programming and the relative ease with which major modification can be made provide for promising experimentation in the teaching-learning process.

In this chapter an attempt is made to outline a variety of ways that the I E system can be employed to accommodate for individual differences. As instruction in elementary schools continues to improve, secondary school teachers will be faced with an increasingly heterogeneous student body. In turn, continued improvements in secondary education will present colleges with a new dimension of variation in student's knowledge and aptitudes. The only certainty that can be gleened from educational research is that effective teaching increases differences among students, albeit, the entire group may be higher in achievement. Continued improvement in school practices will make mass teaching with little flexibility in learning regime available even more obsolete than it is today.

Patterns for Utilizing the Integrated Experience Approach

Good teachers have employed a variety of materials in teaching for many years. While some high school and college teachers resort primarily to the medieval practice of lecturing while students take notes to be memorized (only now ball-point pens and paper have replaced slate and chalk), the effective teacher employs slides, motion pictures, dittoed handouts, various library references, overhead projectors, field observations, and a variety of other materials and techniques. The I E system is in effect an extension of current sound teaching practices in a practicable form. Just how the system can be employed in a given school will vary widely, but probably any school could profit from some utilization of this approach. Some possible applications are suggested below:

(1) *The self-study laboratory for a secondary school science department.*--In many schools there may be only two or three equipped science rooms and these are used for class discussion, testing, etc. Therefore, it would not be feasible nor indeed necessary to convert all of these rooms. However, such a science department might convert one room or better still, an additional room could be equipped for A T instruction. Figure 6. 2 shows an example of a science wing with an A-T

laboratory. Since some aspects of all sciences might be best taught in a good laboratory, only those portions of biology, chemistry, physics, or general science which can be taught most efficiently through A-T system might be scheduled for the A-T room. Some examples of a good A-T topics would be:

Biology	Chemistry	Physics
mitosis	atomic structure	atomic structure
cell structure	orbitals and bonding	vectors
histology	sample reactions	circuits
genetics	some analytic techniques	elementary thermodynamics

General Science
atomic structure
water cycle
solar system
energy conservation

One advantage of a joint facility is obvious from the examples--two or more courses might use the same materials. In this manner the teachers can work together to produce a better lesson and students can save time by quickly reviewing material they may have had in an earlier class. Schedule flexibility can be provided in two ways:

(a) All students in a given class would use the facility only on certain days of the week.

(b) Some students in two or more classes would use a portion of the facility while other students worked in the regular room in the library. This procedure would be especially valuable for review work or supplementary study.

Though the initial preparation for this kind of program would require considerable time, once the materials were developed the maintenance of the facility would not be an appreciable burden and some student help or lay assistant help might be

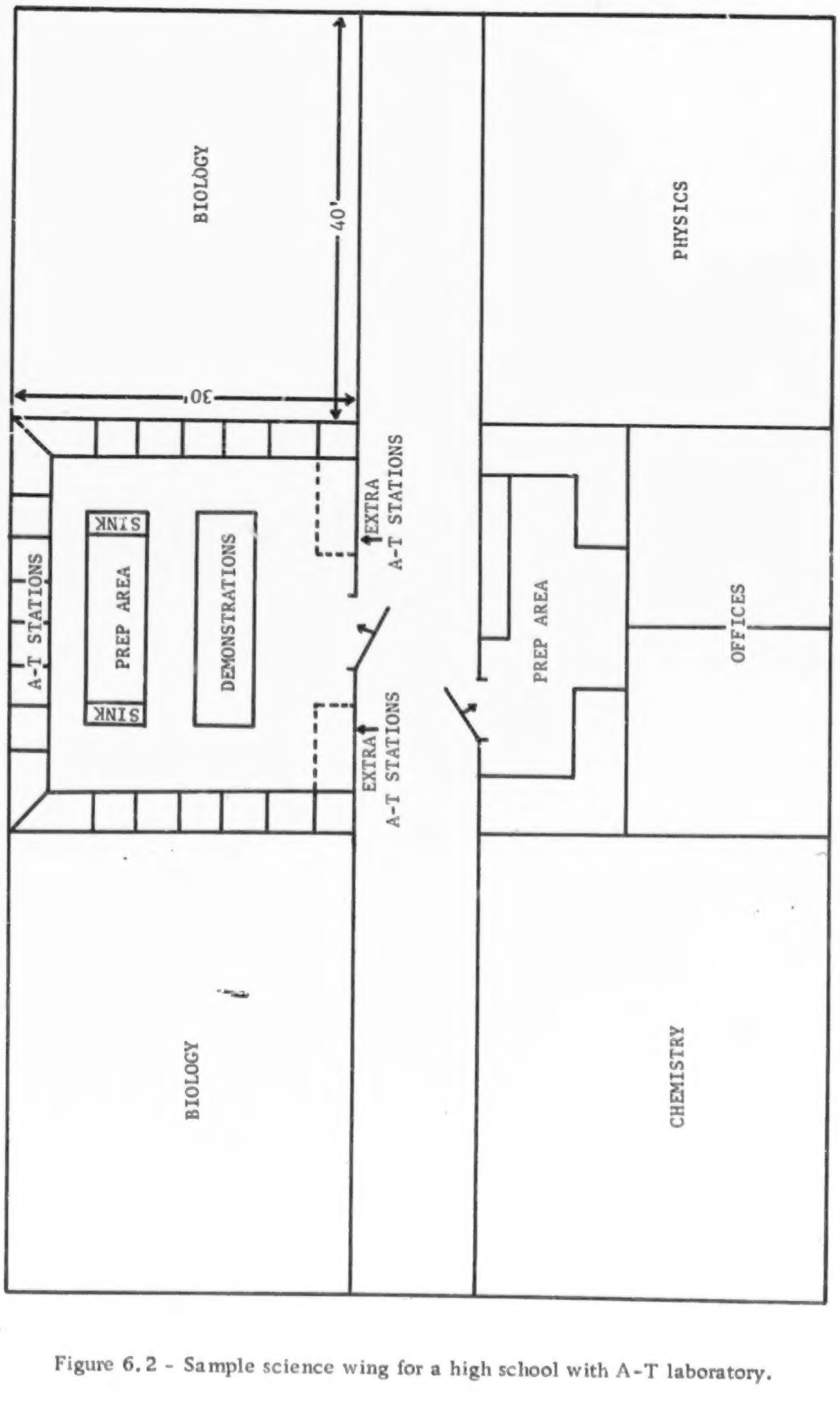

BIOLOGY
40'
30'
PHYSICS
A-T STATIONS
SINK
PREP AREA
SINK
DEMONSTRATIONS
EXTRA A-T STATIONS
EXTRA A-T STATIONS
PREP AREA
OFFICES
BIOLOGY
CHEMISTRY

Figure 6.2 - Sample science wing for a high school with A-T laboratory.

employed. A summer preparation session of six to eight weeks for the initial development would be a good investment for any school system.

(2) *College self-study laboratory.* --One of the problems faced by science departments in almost every college is a shortage of laboratory space. In consequence, student's independent study is highly curtailed or omitted entirely. Nevertheless, the flexibility available in college student's schedules would permit ideal utilization of an A-T study laboratory. The space allocated for this purpose would permit reduction in other laboratory needs and hence more than compensate for the area and expenditure required. For example, an undergraduate program in a biology department could alter scheduling in a manner as below:

(a) General Biology	Without A-T Lab	With A-T Lab
Lectures	2 per week	1 per week
Laboratory	2 - 2 hr. periods per week	1 - 2 hr. period
Discussion	1 hour per week	1 hour per week
Self study	Library and home	2-4 hrs. per week A-T lab
(b) Cytology or Microbiology		
Lectures	3 hrs. per week	2 hrs. per week
Laboratory	1-3 hour period	
Self study	Library and home	3-5 hrs. per week A-T lab
(c) Survey of Plants		
Lectures	2 hours per week	1 hour per week
Laboratory	1-3 hr. period (including field trips)	Field trips and work in A-T lab depending on schedule
Self study	Library and home	A-T lab as needed

(d) Survey of Animals

Schedule similar to (c) above

(e) Plant anatomy

Lectures	2 hrs. per week	none
Laboratory	2-2 hr. periods	A-T lab 4-8 hrs. per week
Discussion	1 hr. per week	1 hr. per week

(f) Comparative Anatomy

Schedule similar to (e) above

The above program might represent one semester's program, with several different courses scheduled in alternate semesters. In this program a department with 300 to 800 enrollments could probably teach all of the classes in a single A-T laboratory with one laboratory assistant available throughout the day and evening. Course instructors would be available for advice and counsel, but since extensive direct instruction via audio tape would be available, much routine questioning can be avoided.

A sample laboratory layout is shown in Figure 6.3.

An additional advantage to such an A-T laboratory for the smaller college would be that students would have some opportunity to survey the entire departmental program simply through observing demonstrations and "over coffee" discussions with colleagues met through the A-T laboratory. Review of earlier course work would obviously be facilitated.

Large biology departments may find it necessary to develop two or three A-T laboratories. The combination of courses assigned to any one laboratory would be determined in part by the kind of supplies and facilities best grouped together and the ease of supervision. Two or three botany courses might be better grouped together than a botany course, zoology course and microbiology course.

(3) *Cooperative programs with other schools.* --One of the promising avenues for use of A-T programmed lessons is in cooperation between colleges and high schools. A college course developed on an A-T programed basis can be easily

adapted for use as a special offering in a high school. In English literature, for example, a college expert on contemporary American novels could provide his A-T material and perhaps visit the high school once each week for a live lecture-discussion. The high school English teacher would be a competent A-T supervisor and she would also profit from the experience.

In the science areas, A-T programmed lessons could serve as a primary method for offering advanced courses in high schools. Since much of the needed equipment and supplies could be included in the A-T cooperative program, the cost of such programs to secondary schools would be substantially less than similar courses run independently by the schools. Moreover, cooperative course offerings would facilitate liaison between local high schools and colleges, a liaison very much in need of development in many communities. The fact is that some high schools have better facilities and support for advanced course offerings than local colleges. These colleges would profit from a cooperative program where highly trained college personnel could be employed more efficiently and meager supply budgets might be extended.

Another form of cooperative A-T program development would be intercollege course exchanges or coordinate planning. Small colleges that offer courses on alternate semesters or alternate years could substantially extend their resources by coordinated planning and sharing of A-T programmed courses. For advanced courses, all colleges and universities would find reciprocal uses of A-T programmed courses advantageous. A specialist at one school could develop a course in algology, for example, including illustrative materials. A botanist at another college could supervise instruction through the borrowed A-T program and perhaps reciprocate by offering an A-T programmed course in paleobotany. Departmental offerings at both schools would be extended without proliferation of staff and heavy investment in specialized slides and equipment. Standard equipment like microscopes, analytic balances, etc. would of course be needed, but this would be available on all campuses.

(4) *Other educational opportunities provided by the integrated experience approach.* --Adult education is increasingly a problem in contemporary society. The rate of job obsolescence is increasing and most positions require continuous education in the highly competitive labor market. While correspondence study has long been valued as an adjunct to formal school instruction, substantial extension of home study is

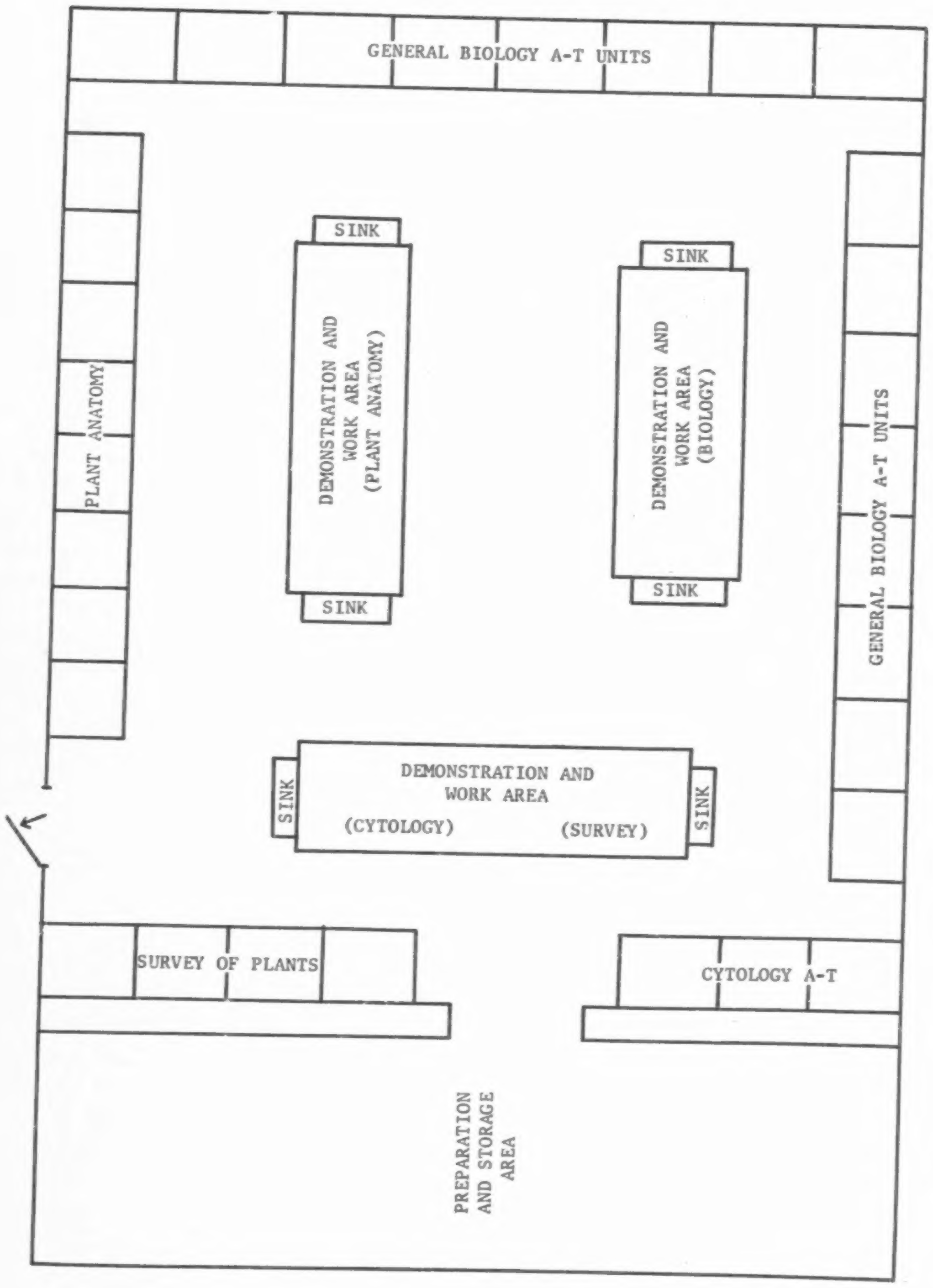

GENERAL BIOLOGY A-T UNITS
PLANT ANATOMY
SINK
DEMONSTRATION AND WORK AREA (PLANT ANATOMY)
SINK
SINK
DEMONSTRATION AND WORK AREA (BIOLOGY)
SINK
GENERAL BIOLOGY A-T UNITS
SINK
DEMONSTRATION AND WORK AREA
(CYTOLOGY)
(SURVEY)
SINK
SURVEY OF PLANTS
CYTOLOGY A-T
PREPARATION AND STORAGE AREA

Figure 6.3 - Sample multi-course A-T biology laboratory.

necessary. In many subject areas, audio programmed courses can be very effectively used in home study. Though mailing costs would be greater than for conventional correspondence courses, the incentives provided by the multi-media A-T program would more than compensate for the added costs to many students. By comparison with commuting costs, an A-T course, including cost for rental of needed equipment, would be substantially lower in many cases. Though home study would be limited in science areas, certain courses could be taught if rental "equipment packages" were made available. We would not recommend offering any science course for home study unless adequate laboratory experience could be provided in some manner. In some cases, this might be accomplished by a once-per-week visit to the school laboratory, for example on Saturday mornings.

The enormous advances in knowledge result in an inescapable obsolescence of courses and printed materials. Continuous updating is necessary, but even with this, some of the exciting areas of new discovery are difficult to incorporate into courses until several years following the initial work. Partly this is due to the fact that only the experts in a given area have sufficient mastery of the subject to interpret the new discoveries. Here, then, is another area where A-T programs can conveniently enrich the course offering; specialists can be obtained to prepare a single lesson, including illustrative material and this can be added in to the A-T programmed sequence. The enormous schedule flexibility makes such additions and deletions relatively simple.

The library will remain a principal resource for study; we find that most libraries are adding to their responsibilities maintenance of selected audio-visual materials. In many schools learning resource centers are developing where the conventional library is an integral part of a larger facility. These learning resource centers provide ideal opportunities for utilizing A-T programmed lessons for enrichment purposes. In elementary schools, secondary schools, and colleges, selected "reference programs" could be developed, perhaps utilizing materials prepared by experts in given fields. Reading will continue to be the most important single avenue for self education, but learning through multi-media presentation is likely to increase markedly in the future as enrichment programs and continuing education is further extended. Most librarians would welcome opportunities to develop instructional facilities to utilize audio programmed material in conjunction with other library programs.

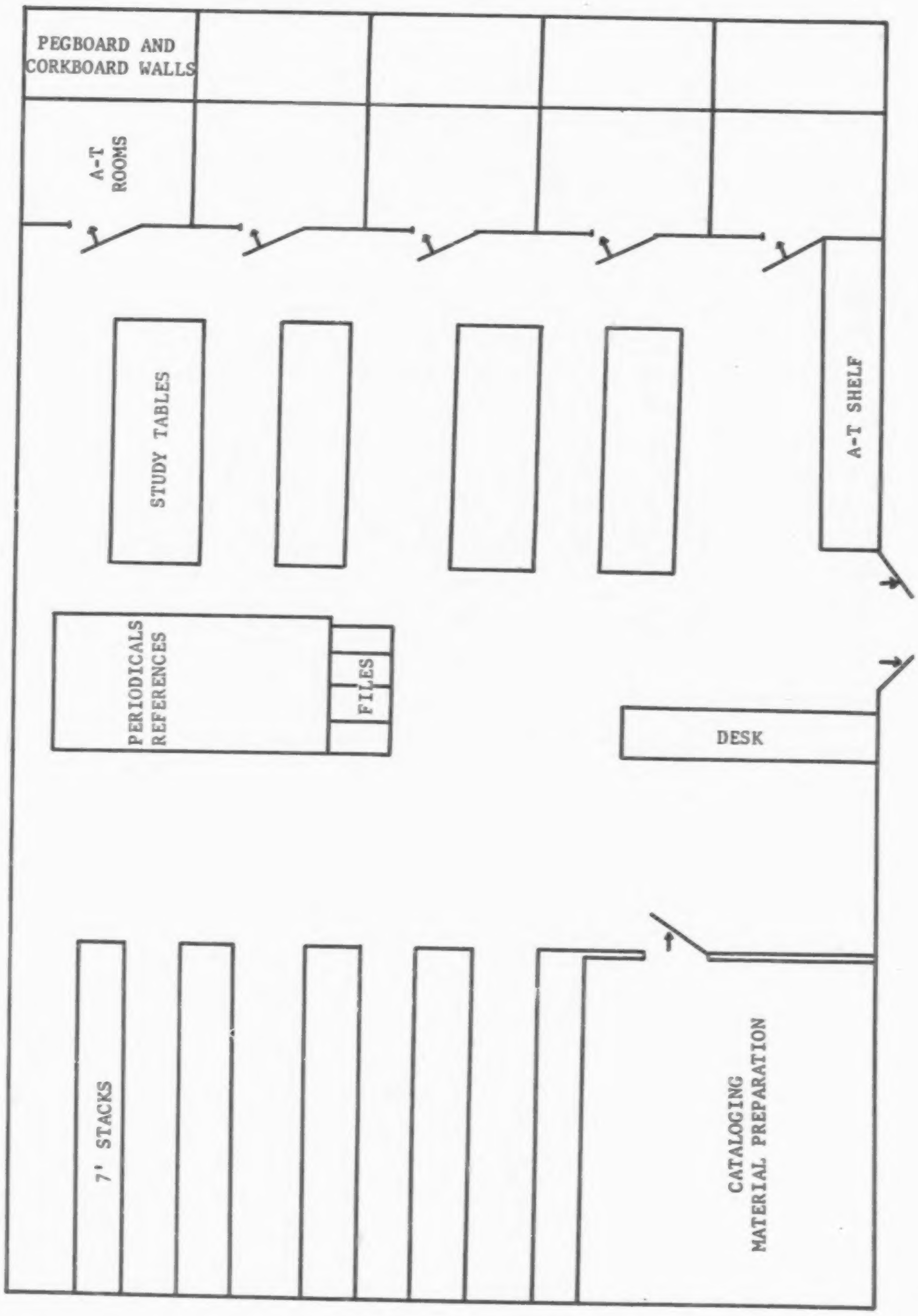

PEGBOARD AND
CORKBOARD WALLS
A-T ROOMS
STUDY TABLES
A-T SHELF
PERIODICALS
REFERENCES
FILES
DESK
7' STACKS
CATALOGING
MATERIAL PREPARATION

Figure 6.4 - A small learning resource center.

In Figure 6.4 a small learning resource center for a secondary school or college is shown. The accent is on encouraging use of the A-T materials. "Perusing" A-T programs can become an important and enjoyable educational experience for all students. Larger centers would differ primary in that more stacks and study units would be available. Adjoining assembly rooms and conference rooms would also be desirable where space permits. Each A-T room should have available a tape recorder, record player, 8mm cartridge and 16mm projectors and other materials depending on utilization.

In Conclusion

This book is an attempt to encourage teachers at all levels to explore more and better ways of providing students with opportunities to learn. There are no magic formulas for teaching success. Like farming, good teaching requires hard work; but successful agricultural practice today requires considerable application of new techniques, chemicals, and marketing skill. Most teachers apply a comparatively small part of the knowledge available on teaching to the cultivation of students' minds when compared with the modern farmer's application of knowledge in his cultivation of plants and animals.

Truly, we face a crisis. Contemporary society will require vastly increased educational productivity. We submit that audio-programmed lessons, used in conjunction with carefully planned, integrated experiences can make a contribution to the improvement of instruction. The authors would welcome comments and suggestions from teachers who try this approach.